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Essays in Macroeconomics

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Doctoral Thesis
ESSAYS IN MACROECONOMICS

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Abstract: The thesis consists of three chapters in form of separate papers. Two of the chapters focus on family labor supply and its effects on the business cycle behavior of hours worked. The third chapter analyses the sources of economic growth in Belarus.

The first chapter, *Real Business Cycles in Model Economies with a Two-Person Household*, studies model economies with a representative two-person household. The standard RBC model cannot replicate the negative correlation of hours with aggregate labor productivity which we observe in the U.S. data (-0.18). I show that extending the standard model to include a two-person representative household, home production and extensive margin decision on labor market participation can generate this negative correlation.

In the second chapter, *Accounting for Labor Productivity Puzzle*, I show that an increase in the share of two-earner households in the U.S. and corresponding changes in labor supply behavior have implications for aggregate business cycles. In particular, it may explain why in the recent decades aggregate labor productivity in the U.S. became countercyclical (labor productivity puzzle). I build a model with heterogeneous one- and two-earner households and aggregate technology shocks, and calibrate it to the current U.S. data. I impose the household structure change in the model and show that the behavior of labor productivity changes from procyclical to countercyclical.

The third chapter, *Belarusian Economic Growth Decomposition*, written in co-authorship with Dzmitry Kruk, investigates the sources of the extraordinary growth Belarus experienced in 2000's. Belarus stands out from the rest of post-Soviet transitional countries. The economic reforms in the country were limited, and Belarusian economy does not rely on natural resource rents. We carefully reconstruct the capital series for Belarus and perform the growth accounting. We find that Belarus mainly benefited from extensive growth through capital accumulation which quickly depleted its potential.

Real Business Cycles in Model Economies with a Two-Person Household*

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Abstract

The standard RBC model cannot replicate the negative correlation of hours with aggregate labor productivity which we observe in the U.S. data (-0.18). We show that extending the standard model to include a two-person representative household, home production and extensive margin decision on labor market participation can generate this negative correlation. After a bad shock the least productive household member exits the market, average productivity increases and hours drop. The correlation of hours and productivity in the model economy is -0.31. We also show that all three elements of the model (two-person household, home production and extensive margin decisions) are crucial to generate negative correlation of hours and productivity.

Keywords: Business Cycles, Home Production, Labor Supply, Two-Earner Households
JEL Classification: C68, E32, E24, J22

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1 Introduction

The standard RBC model does not replicate well the behavior of aggregate hours worked over the cycle. In the RBC model, the volatility of hours is too low compared to the U.S. data, and the correlation of hours with aggregate labor productivity is positive, while in the U.S. data it is negative. The literature has paid a lot of attention to the lack of volatility in hours. This paper focuses on the negative co-movement of hours and productivity.

The standard RBC model, which employs the representative household of one person, cannot generate the negative correlation of aggregate labor productivity and hours. The representative agent in the standard model has no option of exiting the labor market, and has only two options of time use: work or leisure. Including a two-person household with an option to exit the labor market for one of the household members, and adding home production into an otherwise standard model generates the negative correlation. Additional option of productive time use (home production) and labor decisions on the extensive margin together with household decision-making increase the volatility of labor supply responses.

When a two-person household with the members of different productivities faces negative TFP shock, household hours worked are reallocated into home production. The household member with higher productivity, however, reallocates less hours from the market work. It is optimal for the household that the least productive household member shifts more hours into home production. Given the fixed cost of labor market participation, the least productive member may even quit the labor market altogether. As a general result, more productive household member decreases her hours worked on the market less than the least productive household member. Consequently, in the two-person household model aggregate labor supply decreases mostly due to the low-productivity member, and aggregate labor productivity increases. We do not observe the similar effect in the single-person household models even with heterogeneity, as income effects are stronger, and they restrict the responses of the low-productivity agents.

To separate the effects of home production, time cost resulting in extensive margin decisions, and joint household decision-making, we solve a sequence of economies containing one separate feature only. We start with an introduction of the home production into the otherwise standard model, and find that it increases the relative volatility of hours, but it is not enough to generate the negative correlation. We proceed with studying the economy with a representative two-person household without extensive margin decisions or home production, which generates results close to the standard RBC model. Next, we consider a two-person household plus a time cost of labor force participation, which generates the extensive margin decisions in the RBC model. We find that only unrealistically high values of intertemporal labor supply elasticity can generate the negative correlation between productivity and hours in this case. Negative correlation of hours and productivity emerges only in the model with all three features: a two-person household, extensive margin of labor force participation and home production.

The additions to the standard RBC model made in this paper are quantitatively important and relevant to labor supply. According to the Bureau of Labor Statistics American Time Use Survey (ATUS) for 2003-2013 (see Horrigan and Herz, 2005), average American spends 22.8% of his discretionary time working on the market, and a comparable 22.3% working at home. Literature (f.e. Gomme and Rupert, 2007) stresses how important it is to consider the home production sector in calibration, even if the model itself does not consider home production explicitly. Seminal papers by Benhabib et al. (1991) and Greenwood and Hercowitz (1991) have shown that the introduction of home production increases responses of labor supply to aggregate shocks. We explore the effects of home production on the two-person household labor supply where labor specialization may be present.

Around 60% of working-age population in United States are married, and around 70% of the labor force participants live in multiple-earner households. People living in the same household usually make decisions together, and that affects their labor market behavior. Adjustments to the shocks in the multi-agent household happens not only through changes in time allocation of one agent, but also through a change in allocation of hours worked among household members. Greenwood and Guner (2008) explore long-run technology growth in the model with couples and home production to explain recent changes in labor market participation of men and women. Guner et al. (2012) consider how tax reforms may affect labor supply of families. Ortiguiera and Siassi (2013) show that in multi-person households labor supply decisions are an important source of insurance against individual shocks. Our paper contributes to the literature on multiple-agent households by underlining the importance the mechanism of shock response through reallocation of hours to one of the household members.

Most of aggregate fluctuations of labor supply can be explained by the extensive margin decisions (people entering or exiting the labor market.) In seminal works Rogerson (1988) and Hansen (1985) introduce extensive margin decisions by considering indivisible labor models with lotteries. They show that extensive margin decisions generate the increased volatility of aggregate hours worked. Cho and Rogerson (1988) achive similar results by considering a two-person representative hosehold and allowing for external margin decision.

Cho and Rogerson (1988) introduce a fixed utility cost of work in a two-person representative household model. Instead of the fixed cost we explicitly consider the time cost of working (commute time) and home production. Unlike Cho and Rogerson (1988), who use log utility function, we use the realistic values of labor supply elasticity. Under these values of elasticity the main findings of Cho and Rogerson (1988) do not hold, and the correlation between hours and productivity is still positive.

When we calibrate the model to the U.S. economy, we find that the extended model improves on the co-movement of hours and productivity compared to the standard RBC model. In the U.S. post-WWII data two of the main features of the co-movement of hours and productivity are that hours are almost twice as volatile as productivity and that the correlation between hours and productivity is negative. In contrast, in the standard RBC model it is productivity that is twice as volatile as hours and the correlation between hours and productivity is positive.

The extended model generates the correlation of hours worked and labor productivity is -0.31, and volatility of hours relative to the volatility of productivity is 1.43. The correlation coefficient between hours and productivity in the model is not far from the correlation of -0.18 observed in the U.S. economy, while the relative volatility of hours falls short of the data's 1.82. The volatility of hours relative to output, however, is similar to U.S. economy (1.17 in the data and 1.21 in the model).

2 The Model Economy with Home Production and a Two-Person Household

In this section we outline the model with three elements - representative two-person household, home production and fixed cost of labor market participation - which make it distinct from the standard, representative-agent RBC model. Since we want to disentangle the effects of all three distinctive elements of the model, we formulate the model keeping the possibility to exclude each element. We will then study the full model (model 2PHF) and its versions without some of the elements: a model version with home production only (model H); a model version with a two-person household only (model 2P); and a version without home production, but with two-person household and fixed cost (model 2PF). The full model nests all the other versions for certain parameter values.

The model has two economic agents: a representative household of two (or one for H version) infinitely-lived people who supply factors of production to the market and do homework; and a representative firm that uses these factors to produce the consumption and investment good.

2.1 A household

There are two individuals in the representative household, who we will refer to as a man and a woman. The household members are infinitely-lived. We assume that the household members make decisions together in a Pareto-optimal fashion. Household members consume and save together, enjoy leisure, and work at home and on the market.

2.1.1 Preferences

We can present a decision-making process as a centralized maximization of the expected discounted infinite sum of household instantaneous utilities u_t

$$\max E_t[U_t] = E_t \sum_{t}^{\infty} \beta^t u_t \qquad \beta \in (0,1) \tag{1}$$

The household utility u_t is the weighted sum of utilities of a man and a woman:

$$u_t = \mu u_{1,t} + (1-\mu) u_{2,t}, \qquad \mu \in (0,1) \tag{2}$$

where μ is the utility weight. For the model economy H we will set μ equal to 1. The utility of each person $i = 1,2$ (where subscript 1 stands for a man and subscript 2 stands for a woman) in each point in time depends on the level of shared composite consumption c_t and individual leisure $l_{i,t}$:

$$u_{i,t} = u(c_t, l_{i,t}) \tag{3}$$

We assume the individual utility function $u_{i,t}$ satisfies the usual assumptions of monotonicity and strict concavity. Note that utility is derived from shared consumption of the composite good c_t. The composite good consists of the consumption good produced on the market $c_{m,t}$ and the home-made consumption good $c_{h,t}$ (as in Benhabib, Rogerson and Wright, 1991).

$$c_t = C(c_{m,t}; c_{h,t}) \tag{4}$$

where the function C is strictly increasing and strictly concave.

2.1.2 Endowments

Total time endowment T of agent i can be distributed among leisure l_t^i, hours worked in the market sector $h_{i,m,t}$ and hours worked in home production $h_{i,h,t}$.

$$T_i = l_{i,t} + h_{i,m,t} + h_{i,h,t} + \tau I(i,t) \tag{5}$$

There is a fixed time cost of working τ, the agent only incurs it if she participates in the labor market. We can interpret τ as commuting time. $I(i,t)$ is the indicator function that takes a value of 1 if an agent i is working on the market in period t. For the model versions without the fixed cost (H and 2P) τ will be set to zero[1].

We normalize the productivity endowment of a man is 1, and the relative productivity of a woman is ν.

At period $t = 0$ the household is endowed by k_0 units of capital. We assume $k_0 \in (0, \infty)$. Capital depreciates at the rate $0 < \delta < 1$. Capital moves according to the following law:

$$k_{t+1} = k_t(1-\delta) + i_t \tag{6}$$

The household rents its productive time and capital to the firm at prices w_t and r_t.

[1]Using fixed costs and extensive margin decisions in representative agent models has received its fair share of criticism - the decisions of a single household in this case may not generalize to the aggregation of decisions of multiple households. This criticism also applies here. However, Bornukova (2015) shows that the main mechanism of labor supply decisions presented here also survives in the model with heterogenous households.

2.1.3 Home production technology

The household has access to home production technology, that allows to produce the home production good c_h within household. Home-produced good can be consumed, but cannot be invested. Home production function only uses labor. We omit capital or home-production specific technology shock to focus on the labor supply effects of home production only. In home production, both a man and a woman are equally productive, and labor has decreasing returns to scale:

$$c_{h,t} = A_h H(h_{1,h,t}, h_{2,h,t}) \tag{7}$$

where $h_{1,h,t}$ and $h_{2,h,t}$ are hours spent on homework by a man and a woman, A_h is the productivity of home production; and the function H is increasing in both arguments and strictly concave.

2.2 A firm

A representative firm produces the goods sold on the market. The firm technology is represented by a standard Cobb-Douglas production function, and is subject to a technology shock z_t:

$$Y_{m,t} = e^{z_t} {K_t}^{\alpha} {L_{m,t}}^{1-\alpha} \tag{8}$$

The following autocorrelation process generates the technology shock:

$$z_t = \eta z_{t-1} + \epsilon_t, \qquad \epsilon \sim N(0, \rho^2) \tag{9}$$

The firm employs aggregate labor $L_{m,t}$, or the sum of the market labor supply of all agents corrected for productivity:

$$L_{m,t} = h_{1,m,t} + \nu h^w_{2,m,t}, \qquad \nu \in (0, \infty) \tag{10}$$

Parameter ν reflects relative productivity of a woman in the market production.

The good produced be the firm can be either consumed or invested. Formally,

$$Y_{m,t} = c_{m,t} + i_t \tag{11}$$

2.3 Definition of equilibrium

Given initial conditions $k_0 > 0$ and z_0, and a stochastic process for shocks $z_t = \eta z_{t-1} + \epsilon_t$, a competitive equilibrium consists of a household policy $\{c_{m,t}(z_t, k_t),\ h_{1,m,t}(z_t, k_t),\ h_{2,m,t}(z_t, k_t),\ h_{1,h,t}(z_t, k_t),\ h_{2,h,t}(z_t, k_t),\ i_t(z_t, k_t)\}_{t=0}^{\infty}$, a firm's policy $\{K_t(z_t, k_t),\ L_t(z_t, k_t)\}_{t=0}^{\infty}$, and a vector of prices, $\{r_t, w_t\}_{t=0}^{\infty}$, such that:

(i) Given the vector of factor prices $\{r_t, w_t\}$ and the state k_t, z_t, the household policy solves household maximization problem:

$$\max E_t \sum_{t=0}^{\infty} \beta^t (\mu u_{1,t} + (1-\mu) u_{2,t}) \tag{12}$$

subject to:

$$c_t = C(c_{m,t} c_{h,t}) \tag{13}$$

$$c_{h,t} = H(h_{1,h,t}, h_{2,h,t}) \tag{14}$$

$$c_{m,t} + i_t = w_t h_{1,m,t} + \nu w_t h_{2,m,t} + r_t k_t \tag{15}$$

$$T = l_{1,t} + h_{1,m,t} + h_{1,h,t} + \tau I(1,t) \tag{16}$$

$$T = l_{2,t} + h_{2,m,t} + h_{2,h,t} + \tau I(2,t) \tag{17}$$

where

$$I(i,t) = \begin{cases} 1 & \text{if } h_{i,m,t} \neq 0 \\ 0 & \text{if } h_{i,m,t} = 0 \end{cases}$$

$$k_{t+1} = k_t(1-\delta) + i_t; \tag{18}$$

(ii) Given the vector of factor prices $\{r_t, w_t\}$ and shock z_t, aggregate quantities K_t, L_t solve the firm's maximization problem:

$$\max\{Y_{m,t} - w_t L_t - r_t K_t\} \tag{19}$$

subject to:

$$Y_{m,t} = e^{z_t} {K_t}^{\alpha} {L_{,t}}^{1-\alpha} \tag{20}$$

(iii) The markets clear:

$$K_t = k_t \tag{21}$$

$$L_t = h_{1,m,t} + \nu h_{2,m,t} \tag{22}$$

$$c_{m,t} + i_t = Y_t \tag{23}$$

3 Calibration

In choosing the functional forms, parameter values and calibrating the model, we set several objectives. First is to choose a utility function suitable for the study of labor supply decisions, and to reflect the realistic values of labor supply elasticity. Second is to calibrate the parameters of the model in such a way that the model matches targets in hours worked on the market, and, where applicable, at home, according to the ATUS data. We choose conventional values to the rest of the parameters.

3.1 Functional forms

We assume that individual utility function has logarithmic functional form:

$$u_{i,t} = \log c_t + \sigma \frac{l_{i,t}^{1-\gamma}}{1-\gamma} \text{ for } i = 1, 2 \tag{24}$$

with the parameter $\sigma > 0$ specifying the relative value of leisure. The parameter $\gamma > 1$ determines the intertemporal (Frisch) elasticity of labor[2]. The utility function is identical to the ones used in recent aggregate labor supply studies, like Prescott and Wallenius (2009) or Rogerson and Wallenius (2008).

Composite good is a CES combination of market-produced consumption $c_{m,t}$ and home-produced good $c_{h,t}$. Note that $\frac{1}{1-e}$ in this case is the elasticity of substitution between home and market-produced goods, and a is the weight of market consumption.

$$C(c_{m,t}, c_{h,t}) = (a{c_{m,t}}^e + (1-a){c_{h,t}}^e)^{1/e}, \qquad a \in (0,1), e \in (-\infty, 1) \tag{25}$$

The home production technology is separable in the time contributions of different household members and displays similarly diminishing returns in both arguments:

$$H(h_{1,h,t}, h_{2,h,t}) = {h_{1,h,t}}^{1-\alpha_1} + {h_{2,h,t}}^{1-\alpha_1} \tag{26}$$

[2]Frisch elasticity for this function is given by $\frac{1}{\gamma}\frac{l_i}{h_i}$

Table 1: Time Use Targets

	Average hours per day	As percent of discretionary time
Discretionary time	14.58	100
Market work	3.32	22.8
Men	3.96	27.2
Women	2.71	18.6
Home work	3.25	22.3
Men	2.47	17.0
Women	3.97	27.3
Travel time to work	0.28	1.9
Those who work	0.75	5.1

Averages for adult non-institutionalized population according to ATUS 2003-2013

3.2 Calibration targets

Since the focus of this paper is the behavior of hours, main calibration targets are hours worked in the market and at home. We use American Time Use Survey (ATUS) data for 2003-2013 for the source of data on time use. ATUS is a nationally representative survey of non-institutionalized adult population (over 15 years). We define discretionary time as 24 hours less time spent on personal care activities. Our broad definition of home work follows Ramey (2009) and includes four ATUS categories: household activities (housework), purchasing goods and services (less personal and medical care), caring for household members, and for non-household members. We define market work as time working, time spent on other work-related and income-generating activities. Time spent on travel related to work (for those who work) is the natural definition of the commuting cost. Table 1 documents time use patterns we use as targets.

For the full model the calibration targets to match average hours worked by men and average hours worked by women in both sectors according to American Time Use Survey. For the model H the calibration targets average hours without gender separation. Models 2P and 2PF only target hours worked at home.

Final calibration target is Frisch elasticity of labor. Estimates of Frisch elasticity for males vary from 0.2 to 0.6, according to Domeij and Floden (2006). Since estimates of female Frisch elasticity are typically higher, we will target Frisch elasticity of 0.5, a common choice in labor supply literature.

3.3 Parameter values

As we mentioned earlier, we are going to compare the performance of the full model economy 2PHF with its versions (H, 2P, 2PF) without some of the elements of the model[3]. The models have common calibration targets (focusing on hours worked), but some of the resulting parameter values will be different. For example, it is well-known that the introduction of home production into the otherwise standard model leads to different calibrated relative value of leisure (see Gomme and Rupert, 2007).

We assign some parameter values directly from the data. The fixed time cost τ is set to reflect the commuting cost a working American faces (see Table 1).

The parameter e determines the elasticity of substitution between market and home-produced goods. The estimates of this parameter in the literature range from 0.40-0.45 (McGrattan et al., 1995; Rupert et al., 1995; Nevo and Wong, 2014) to 0.55-0.60 (Aguiar and Hurst, 2007; Chang and Shorfheide, 2003). We choose the value of $e = 0.5$, which corresponds to the elasticity of substitution of 2.

The parameter γ is set to match the target level of Frisch elasticity of labor supply (0.5). Notice that under our parameterization Frisch elasticity depends not only on γ, but also on the hours worked and leisure. It implies that γ will be different for models with and without home production or fixed cost.

We adopt the value for the parameter α_1 (capital share in home production) from Benhabib et al. (1991). The value of $\alpha_1 = 0.92$ reflects the share of capital (home appliances) in home production and coincides with the more recent calibrated value in Duernecker and Herrendorf (2013).

Four parameters - utility weight μ, relative value of leisure σ, share of market good in consumption a, and relative productivity of a woman ν - are calibrated to match the five remaining targets

[3]In versions 2P and 2PF home productivity is set to zero to exclude home production. In the model 2P commuting cost is also set to zero. Model H assigns utility weight only to a man ($\mu = 1$) and sets the time endowment of a woman to zero, converting the model into a representative agent one.

Table 2: Calibrated Values for Model Parameters

Parameter		H	2P	2PF	2PFH	Calibration source or target
Utility weight of a man	μ	1	0.41	0.41	0.64	to match targets
Relative value of leisure	σ	0.07	0.56	0.41	0.10	to match targets
Share of market good in consumption	a	0.41			0.11	to match targets
Frisch elasticity	γ	4.82	7.05	6.59	4.50	to match targets
Relative productivity of a woman	ν		0.65	0.65	0.65	to match targets
Labor share in home production	$1 - \alpha_1$	0.92			0.92	literature
Time endowment	T	1.00	1.00	1.00	1.00	directly from the data
Commuting cost	τ	0	0	0.05	0.05	directly from the data
Substitution between c_m and c_h	e	0.50			0.50	literature
Discount factor	β	0.99	0.99	0.99	0.99	conventional value
Depreciation rate	δ	0.03	0.03	0.03	0.03	conventional value
Autocorrelation of technology shock	η	0.95	0.95	0.95	0.95	conventional value
St.d. of technology shock	ρ	0.01	0.01	0.01	0.01	conventional value
Capital share	α	0.36	0.36	0.36	0.36	conventional value

* In the model H the time endowment of agent 2 is set to 0.

**Since only three calibration targets are suitable for the model H (market hours, home hours and share of home production in GDP), and we still need to calibrate four parameters, we adopt the parameter α_1 from Benhabib, Rogerson and Wright (1991).

in non-stochastic steady state. Since only two calibration targets are suitable for the 2P and 2PF models (market hours of men and market hours of women), and we still need to calibrate three parameters for these model economies, we adopt the value of relative productivity of a woman ν from H2PF calibration.

Parameters β (discount factor), δ (depreciation rate), η (autocorrelation term for technology shock) and ρ (standard deviation of technology shock) are assigned their conventional values, as in Cooley and Prescott (1995).

As expected, the calibrated values of utility parameters σ and γ differ substantially for the models with and without home production. To accommodate more working hours and less leisure, σ is comparably lower for the models with home production. The relative utility weight of a man μ has to go up significantly in the model with both home production and two-person household to generate higher total hours worked by a woman, with μ set to 0.62 in the main H2PF model. The value of γ is set to target Frisch elasticity, which, in particular, depends negatively on the level of leisure. Hence, models with home production require lower γ to generate the same level of Frisch elasticity on the margin.

The calibrated value of relative productivity of a woman ν is 0.65. This is lower than 0.74, an average wage of women relative men in 1979-2012 according to BLS[4] (based on CPS data). Since ν reflects not only the relatively lower productivity of a woman on the market, but also her possible higher productivity in home production, the value looks plausible to us.

4 Business Cycle Properties of the Model Economies

4.1 Main results

The addition of the home production and two-person household into the otherwise standard RBC model introduces new propagation mechanism, which changes significantly the model's properties. In the presence of the fixed cost of working (commuting cost) the least productive household member may decide to drop out of the labor force in certain states. Under our calibration these states are substantially negative technology shocks in combination with above average levels of capital stock. The presence of the home production offers alternative way of productive time use, making the decision to drop out of the labor force more attractive. One immediate consequence of the extensive margin decision is the sizable drop in hours. But since only the least productive member leaves the market, the drop in productive hours is not as sizable, and average labor productivity increases.

Table 3: Business Cycle Properties of the H2PF Model Economy

	Amplitude of fluctuations		Correlations with output	
	Data	H2PF	Data	H2PF
Output	1.64	1.62		
Consumption	0.81	1.29	0.81	0.26
Investment	4.80	5.58	0.85	0.55
Productivity	0.56	0.85	-0.05	0.29
Market hours	1.17	1.21	0.88	0.72

Co-movement of market hours (h) and productivity ($w = y/h$)

	Data	H2PF
$corr(h, w)$	–0.18	–0.31
$\sigma(h)/\sigma(w)$	1.82	1.43

[4]BLS report no. 1045 *Highlights of Womens Earnings in 2012*, October 2013

This new mechanism of propagation of the negative shocks results in the changes in co-movement of aggregate hours and productivity over the cycle. In recessions caused by negative technology shocks productivity and hours may move in different directions, resulting in negative correlation. In the H2PF model featuring two-person households, commuting cost of working and home production the correlation of hours and productivity is -0.31 (see Table 3). Sizable changes in hours worked in case of extensive margin decisions also contribute to the increased volatility of hours and labor productivity. Volatility of hours relative to productivity is 1.43 in H2PF model. The co-movement of hours and productivity in the model is very close to the one in the data: in the U.S. economy correlation of hours and productivity is -0.18, and the hours volatility relative to productivity is 1.82 (see Table 4). This is also a vast improvement over the performance of the standard RBC model, which generates high positive correlation between hours and productivity, with hours being two times less volatile than productivity. However, extensive margin adjustments in individual labor supply imply significant changes in aggregate labor supply in a representative household model like ours. Naturally, the volatility of aggregate hours and labor productivity is higher than in the data.

The possibility to switch to home production in times of negative technology shock on the market also has consequences for the co-movement of the market output and consumption. Market-produced consumption moves together with output except for the cases when the least productive agent drops out of the market. In this case the drop in consumption is much more significant than the drop in output, as home-produced consumption crowds out market-produced consumption. This non-linear relationship of consumption and output contributes to a relatively low correlation of consumption and output, and to higher relative volatility of consumption. In this regard H2PF model fails to match the data and underperforms the standard RBC. Correlation of consumption and output in the model is too low (0.62 in the model versus 0.85 in the data).

Home production and hours worked at home are both countercyclical. When there is a negative technology shock on the market, household members shift more hours into home production, compensating for market consumption. These findings are consistent with seminal works by Benhabib et al. (1991) and Greenwood and Hercowitz (1991). They are also consistent with the empirical findings on the home hours across the world in Blankenau and Kose (2007), or during recent Recession in Aguiar et al. (2013).

Table 4: Business Cycle Properties of the U.S. Economy and 4 Model Economies

	Data	H	2P	2PF	H2PF
Co-movement of market hours (h) and productivity ($w = y/h$)					
$corr(h, w)$	–0.18	0.81	0.97	0.55	–0.31
$\sigma(h)/\sigma(w)$	1.82	1.38	0.29	0.46	1.43
Amplitude of fluctuations, relative to output					
Consumption	0.81	0.51	0.57	0.56	0.85
Investment	4.80	3.25	3.51	3.50	3.38
Productivity	0.56	0.43	0.76	0.76	0.85
Market hours	1.17	0.61	0.35	0.35	1.21
Correlations with output					
Consumption	0.81	0.61	0.62	0.61	0.62
Investment	0.85	0.93	0.91	0.90	0.87
Productivity	-0.05	0.97	0.96	0.95	0.29
Market Hours	0.88	0.99	0.78	0.77	0.72

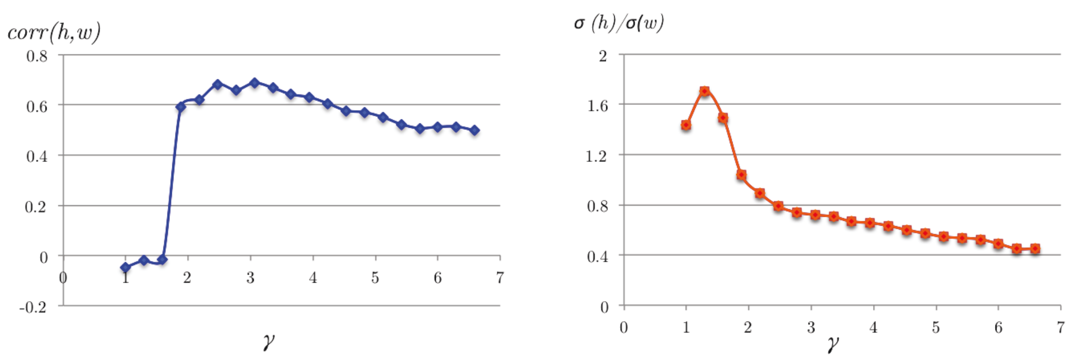
4.2 Effects of different model features

As we have mentioned before, our intent is not only to see the business cycle properties of the more realistic model which adds three new features to the otherwise standard model, but also to disentangle the effects of each separate feature on the final model's performance. Our special interest is which of the three added features - home production, two-person household, fixed cost of working - contributes to the improved performance in accounting for the co-movement of hours and productivity. As it turns out, the combination of all three is key to the results.

Table 4 documents the business cycle properties of three different models. As we said before, model H includes only home production, model 2P studies the effects of two-person household, and model 2PF investigates the effects of fixed cost in two-person household setting (modeling fixed cost in a single-person representative household is not fruitful, as exit from the labor market is not an option for a sole earner, and we cannot expect the results to be different from the standard RBC model).

The model H introduces an alternative time use - working at home. Home production is a natural substitute of market production, and since it is not subject to productivity shocks, during bad times (negative technological shocks on the market) the household partially reallocates hours not only into leisure, as in the standard RBC model, but also into home production. The household no longer has to sacrifice consumption in order to decrease market hours - the increase in home consumption compensates for drop in market consumption. The major result is higher volatility of output and market hours compared to the standard model, a result which was well-established in the seminal works of Benhabib et al. (1991) and Greenwood and Hercowitz (1991). However, unlike in the seminal papers cited, market hours volatility is still lower than in the data. The difference in market hours volatility comes from different labor supply elasticities. Both Benhabib et al. (1991) and Greenwood and Hercowitz (1991) used logarithmic utility from leisure in their calibration, corresponding to $\gamma = 1$ under our parametrization. This parameter choice implies unrealistically high levels of intertemporal (Frisch) labor supply elasticity, while our calibration of γ targeted the micro-estimated levels of Frisch elasticity resulting in higher γ. Lower Frisch elasticity implies less willingness to adjust levels of leisure over the cycle, which in turn implies lower hours volatility. Despite low hours volatility, model H generates the co-movement of hours and productivity similar to the one in the data.

Figure 1: Co-movement of hours and productivity in the 2PF model under different values of γ



A: Correlation

B: Relative volatility

Introduction of the two-person representative household into the RBC model does not affect the business cycle properties. 2P model is not different from a standard RBC model in performance. The most significant difference comes in the form of the lower correlation of hours and output. This lower correlation is the direct result of the disconnect between hours worked and productive labor supply, as less productive agent adjusts hours more. As can be seen from Table 4, both models 2P and 2PF demonstrate similar business cycle behavior despite the presence of the fixed cost in

2PF. Under our calibration the fixed cost of working does not generate extensive margin decisions: the commuting cost is not high enough to make the exit from labor market attractive under any states. Sensitivity analysis shows that the result holds for any values for the commuting cost τ from 0 to 40 per cent of discretionary time. Very low values of the parameter γ and respectively high Frisch elasticity can, however, generate labor market exits in certain states, and deliver results comparable to the H2PF model.

Figure 1 depicts co-movement of hours and productivity in 2PF model under different values of γ. For the values close to 1 and corresponding to a very high Frisch elasticity 2PF model generates negative correlation of hours and productivity due to the presence of extensive margin decisions in certain states. In the same fashion the volatility of hours relative to the volatility of productivity explodes once γ approaches 1.

Once we add home production into the mix, we no longer need unrealistically high Frisch elasticity to get the external margin decisions. When the lower-productivity household member exits the labor market, she does not necessarily need to increase her leisure. Instead she invests extra time in home production. Hence, the parameter γ and corresponding Frisch elasticity no longer play crucial role in H2PF economy, and labor market exits happen even under plausibly low Frisch elasticity values.

5 Concluding Remarks

We have studied the business cycle properties of a RBC model extended with three realistic features: two-person household, time cost of working and home production. The model matches very well the co-movement of market hours and aggregate labor productivity. Unlike the standard RBC model, the extended model can generate the negative correlation of hours and productivity, and also high relative volatility of hours. The new mechanism of adjustment to shocks generates these results. The mechanism relies on the external margin labor supply decisions. In certain states with negative technology shock the least productive household member may decide to drop out of the labor market. As a result, hours worked drop significantly, and aggregate productivity increases.

All three new features of the model are essential for the results. Two-person representative household and the presence of the fixed cost of labor market participation make external margin decisions possible. In the standard one-person representative household the only household member will always work, otherwise the economy would stop. Time cost creates incentives to exit the labor market in certain situations. Home production offers another productive way of time use. Without home production in the model, we would need unrealistically high levels of labor supply elasticity to generate the external margin decisions.

These findings shed new light on the aggregate labor supply behavior over the cycle. In particular they show that even with the Frisch elasticity consistent with microeconomic evidence RBC models can match the level of hours volatility observed in U.S. data. Further research should explore this mechanism in the setting with heterogeneous households, where the decision of one household member to drop out of the market will not lead to the drastic changes in aggregate hours.

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Accounting for Labor Productivity Puzzle

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May 7, 2015

Abstract

In the recent decades aggregate labor productivity in the U.S. became countercyclical (labor productivity puzzle). At the same time the U.S. experienced dramatic changes in the structure of households due to increased female labor force participation. I show that changes in the household structure and corresponding changes in labor supply behavior can explain the labor productivity puzzle. I build a model with heterogeneous one- and two-earner households and aggregate technology shocks and calibrate it to the current U.S. data. I impose the household structure change in the model and show that the behavior of labor productivity changes from procyclical to countercyclical, as in the U.S. I also show that individual labor supply volatility depends on the role of the earner in the household. Increase in the proportion of multiple-earner households leads to increase in aggregate labor supply volatility.

Keywords: business cycles, family labor supply, multiple-earner households

JEL Classification: C68, E32, E24, J22

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1 Introduction

Aggregate labor productivity has changed its cyclical behavior over the last 60 years from weakly procyclical to countercyclical - the literature refers to this fact as the labor productivity puzzle. At the same time the household structure in the U.S. underwent significant changes, in particular a shift from one-earner to two-earner households. This paper argues that changes in household composition affected the cyclical behavior of productivity through labor supply decisions and may explain the labor productivity puzzle.

Table 1: Correlations of aggregate labor productivity with output and aggregate hours

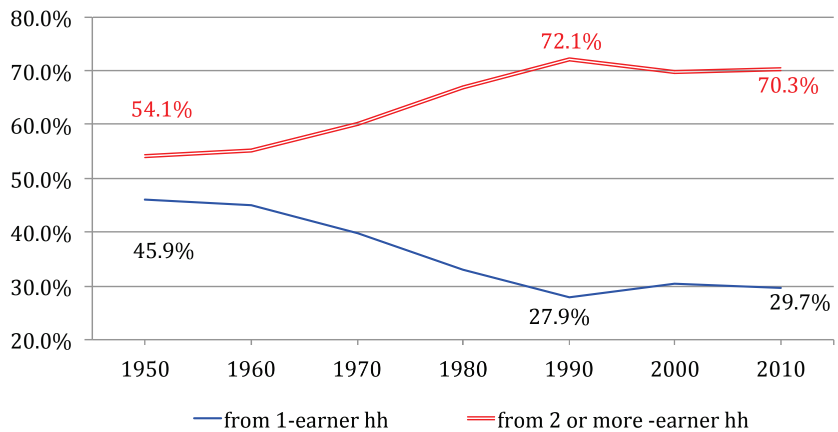
Correlation with:	1950:q1-1979:q4	1980:q1-2009:q4
Output	0.10	-0.27
Hours	-0.38	-0.68

U.S. data. All variables are logged and detrended with HP filter

Labor productivity puzzle manifests itself in the change of the correlation of aggregate productivity with output from 0.10 in 1950-1979 to -0.27 in 1980-2009 (see Table 1; Gali and van Rens (2014) offer more evidence on the change of cyclical behavior of productivity). Aggregate labor productivity increased over the Great Recession, which generated interest in the problem (Mulligan, 2011; Ramey, 2012). At the same time the puzzling negative comovement of hours and productivity, well known before (Hansen and Wright, 1992; Christiano and Eichenbaum, 1992), became more pronounced (Stiroh, 2009). The correlation between hours and productivity changed from -0.38 to -0.68, contrary to the predictions of workhorse macroeconomic models.

Simultaneously with the change in labor productivity behavior, the structure of American households changed. Increased female labor force participation challenged the traditional family labor division as described by Becker (1981). As a result, more and more workers in the labor force come from the two-earner households (see Fig. 1). I argue that their behavior is different from the behavior of the sole earners. In particular, both primary and secondary earners from a multiple-earner households can have more elastic labor

Figure 1: Labor force by household type in the U.S.



supply. This is especially true for the secondary earners, whose role in family monetary income is limited, and hence they can substitute into home production if necessary.

The standard RBC model can generate countercyclical aggregate labor productivity when amended for a two-person household. Intuitively, labor supply becomes much more elastic and volatile over the cycle if the representative household consists of two people, as the secondary earner can easily substitute into home production. In recessions aggregate productivity experiences positive effects as labor supply contracts more significantly than in the one-person model and the contraction is mainly in the less productive part of the labor supply. These effects dominate the decline in TFP, and aggregate labor productivity increases. Since the proportion of two-earner households increased significantly since 1960, this change might explain the switch in the behavior of productivity.

Can the observed increase in the share of two-earner households explain the change in the correlations of aggregate labor productivity with output and aggregate hours? To answer this question I construct a heterogeneous agents model featuring one- and two-earner households. Each household is assigned one of the three types: one-person, two-person one-earner or two-earner household. Each assigned earner can decide to drop out of the labor market and divides time between leisure, working on the market and working at home, while assigned non-earners only have the options of leisure and home production. Agents in all households differ in productivity. The economy is only subject to aggregate technology shock, and there are no shocks to individual productivities. I calibrate the model to the current U.S. economy, and expose it to the exogenous change in the household structure (proportions of three household types) identical to the change which happened in the U.S. from 1950 till 2000.

I compare the cyclical behavior of productivity in the model before the change (with the household structure mimicking the U.S. in 1950) and after the change (the U.S. in 2000). As in the U.S. economy, in the model economy the correlation of productivity and output switches sign from positive to negative, while correlation with hours remains negative, but increases in absolute value. The change in the household structure may explain the labor productivity puzzle.

Higher female labor participation and higher proportion of multiple-earner households contribute to the increase of aggregate labor supply volatility. When I impose the U.S. factual changes in household structure into the model economy, the volatility of hours increases from 1.01 (for calibration consistent with 1950) to 1.36. Similar changes in hours volatility happened in the U.S. economy: it grew from 1.07 in 1950-1979 to 1.32 in 1980-2009.

Existing literature has already offered different explanations to the labor productivity puzzle. McGrattan and Prescott (2012) claim that the puzzle is the result of mismeasurement: as intangible capital plays higher role in the modern world, the measurements of productivity and its cyclical behavior become more biased. Gali and van Rens (2014) focus on the changes in labor market frictions: as frictions decline, employment becomes more responsive to cyclical changes, generating negative relationship of output (and hours) with productivity. This paper offers another explanation which works through higher volatility in hours. But I assume that the source of this higher volatility is more people from two-earner households in the labor force (see Fig. 1) due to changes in household labor division.

The paper also contributes to the discussions of labor supply elasticities(Chetty et al., 2012; Dyrda et al., 2012; Wallenius and Rogerson, 2012; Prescott and Wallenius, 2012) by stressing the household structure as important determinant of labor supply behavior. In two-person households decisions on extensive margin play higher role, generating higher aggregate labor supply elasticity from utility parameters calibrated with micro estimates. Many empirical studies focusing on labor supply elasticity use female gender as an implicit proxy for the secondary earner position and find higher elasticity for female labor supply. To the best of my knowledge, the only empirical study paying attention to the differences between primary and secondary earners is Peterman (2012), finding that secondary earners have more elastic labor supply. This work stresses the differences in labor supply of only, primary and secondary earners.

2 Changes in the Structure of U.S. Households, 1950-2010

After the World War II two major trends shaped the earner structure of American households. One of them is the "quiet revolution" in the socio-economic status of women and higher female labor force participation. The other one is the drop in the marriage rates, accompanied by the increase in divorce rates.

Increasing labor force participation of women is one of the most vivid changes in the socio-economic life of the United States after the World War II. Before the war married women rarely worked. In 1955 only 26.3 per cent of married women were actively working or looking for work; by the year 1990 the number grew to 58.2 per cent and remained fairly constant afterwards. At the same period of time the labor force participation of married men declined slightly from 88.2 per cent in 1955 to 77.3 per cent in 2000[1] .

There is no clear consensus in the literature on the main factor contributing to the dramatic increase in the labor force participation of married females. Most often the works cite progress in the home production technologies (Greenwood et al., 2005; Jones

[1]Data in this paragraph are from the U.S. Census Bureau, *Statistical Abstract of the United States*

et al., 2003), the invention of the pill (Goldin and Katz, 2002) or cultural shifts due to World War II (Fernandez et al., 2004).

The direct consequence of the higher participation of married women is the increase in the proportion of marriages where both partners work, i.e. two-earner married households. The drop in the participation of married men offsets this effect only insignificantly.

Decline in marriage along with the increase in divorce constitute another important feature of the socio-economic development in the post-war U.S.. Between 1950 and 2000 marriages per 1,000 unmarried women fell from 211 to 82; the divorce rates, on the opposite, grew from 11 to 23 per 1,000 married women. As a result, over the same period the share of married women fell from 82 to 62 percent (Greenwood and Guner, 2009).

Part of the decline in marriage was offset by higher cohabitation rates (Lundberg and Pollak, 2013). Nevertheless, late and less common marriages coupled with higher divorce rates lead to the increase in the proportion of single-person and single-parent households.

Table 2: Changes in household structure in the U.S., 1950-2010

	1 adult	2 or more adults	
		1 earner	2 or more earners
1950	15.8%	50.2%	34.0%
2000	21.3%	28.2%	50.5%

Only households with earners are included. Source: Census data from IPUMS-USA

Table 2 describes the relevant changes in the earner structure of the households from 1950 to 2000. Higher female labor force participation manifests in the increase of the share of households with two or more earners from 34.0% to 50.5%. At the same time the changes in the marriage/divorce trends contributed to the increase in the proportion of households with a single adult and earner.

Depending on the type of the household and the role of a person in the household one can define four different types of agents by the peculiarities of their labor supply. Type I is the primary earner of a single-adult household, whose behavior has been extensively studied in the representative agent models. Her labor supply results from an autonomous choice among consumption, leisure, household production and market work. Type II is the primary earner in the two-person household. Her labor supply decision takes into account the fact that there is another adult in the household taking care of (the part of) household production, and hence, she is less likely to substitute into home production in case of adverse events on the market. Type III is the primary earner in the two (or more)-adult and two(or more)-earner household. While she is the primary breadwinner, she is not the only one, and hence her labor supply might be more elastic than that of Type I or Type II. Type IV, the secondary earner, theoretically is the most elastic type: she can easily substitute into the home production in recessions, as there is no one at home already taking care of it, and there is another, more prolific earner in the household that can compensate for the forgone market earnings.

The socio-economic changes that happened over the course of the last 60 years have significantly shifted the balance on the labor market towards the more elastic types. While Type II earner was a dominant type in 1950, by 2010 Type I, Type III and Type IV increased their presence substantially, changing the aggregate labor dynamics. Unfortunately, empirical studies of labor supply elasticity rarely take into account the household structure and the position of the individual in the household, focusing instead on sex and marital status, which are imperfect proxies.

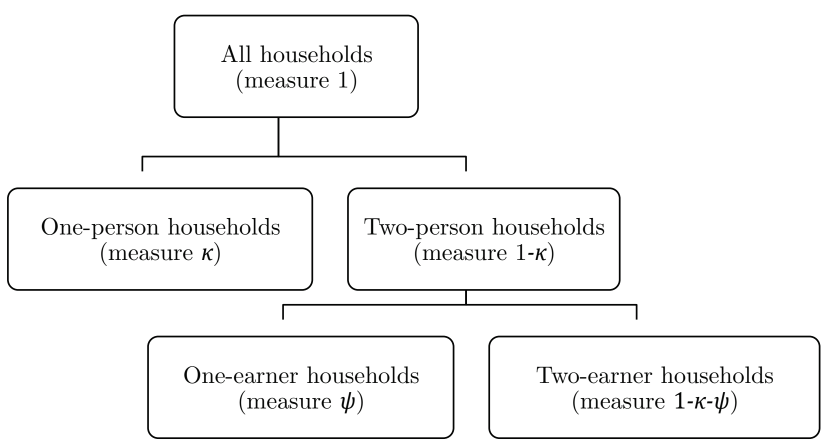
3 The Model Economy with One- and Two-Earner Households

In this section I construct the model with the three types of households - one-person households, two-person one-earner households and two-person two-earner households. All household members within and across households are heterogeneous in labor productivity. However, I abstract from the idiosyncratic productivity shocks and focus on fluctuations in aggregate productivity only.

3.1 Demography

The model economy is populated buy a measure 1 of households. Households may be populated by one person only (with the measure of one-person households equal to $\kappa \in (0,1)$) or by two persons (with the corresponding measure of $1-\kappa \in (0,1)$). One-person households and individuals are indexed with i, two-person households with two earners are indexed with j, and $1j$ and $2j$ index the primary and the secondary earner correspondingly. Two-person households with one earner are indexed with k, $1k$ is for the only earner, $2k$ for the stay-at-home agent. I assume that individuals in two-person households have separate utility functions, but they make decisions about individual consumption, market and home work and leisure together, in Pareto-optimal fashion. They also make capital and make saving decisions jointly. Hence the decision-making process can be represented by the maximization of the household utility function.

Figure 2: Household Structure in the Model Economy



Each two-person household belongs to one of the two types: it is either a one-earner or a two-earner household. The measure of one-earner households is $\psi \in (0, 1-\kappa)$. Figure 3.1 depicts the household structure of the model economy. In one-earner household only one person (indexed $1k$) decides how much time to spend on the market and in home production - I impose the restriction of zero market hours for the second person, who may only take part in the home production. In two-earner households both individuals may decide whether to work or not and how many hours to spend working on the market and at home.

3.2 Preferences of one-person households

A one-person household i is maximizing the expected discounted flow of the instantaneous utilities with a discount factor β:

$$U_{i,t} = E_t \sum_{t}^{\infty} \beta^t u_{it} \tag{1}$$

Household i has the instantaneous utility function which depends on consumption and leisure:

$$u_{i,t} = u(c_{i,t}, l_{i,t}) \tag{2}$$

The household (and in this case, individual) utility depends on the individual consumption of the composite good $c_{i,t}$ and individual leisure time $l_{i,t}$. Composite good is a combination of market-produced good consumption $c_{i,t}^m$ and home-produced good consumption $c_{i,t}^h$:

$$c_t = C(c_{m,t}; c_{h,t}) \tag{3}$$

where the function C is strictly increasing and strictly concave.

3.3 Preferences of two-person households

I assume that two-person households have a joint maximization problem. A two-person household j (or k for two-person one-earner household) is maximizing the expected discounted flow of the sum of instantaneous utilities of household members $1j$ and $2j$ (or $1k$ and $2k$):

$$U_{j,t} = E_t \sum_{t}^{\infty} \beta^t (u_{1j,t} + u_{2j,t}) \tag{4}$$

Instantaneous utility functions of household members $1j$ and $2j$ are $u_{1j,t}$ and $u_{2j,t}$, and they depend on individual composite consumption and individual leisure as in Eq. 2. The amounts of leisure can be different for the individuals within the same household. The amount of individual composite consumption, however, is determined by $\frac{c_{j,t}}{1+\chi}$, where $c_{j,t}$ is a total composite consumption of the household j, and $\chi \in (0,1)$ is the parameter of the economies of scale. $\chi = 1$ if there are no economies of scale in the two-person households, and lower χ implies higher economies.

3.4 Endowments

Each agent is endowed with T units of time each period, and she is free to allocate time among leisure $l_{i,t}$, hours worked at home $h^h_{i,t}$, hours worked in the market $h^m_{i,t}$:

$$T = l_{i,t} + h^m_{i,t} + h^h_{i,t} + \tau \cdot I(i,t) \tag{5}$$

There is a fixed time cost of working τ, the agent only incurs it if she participates in the labor market. I can interpret τ as commuting time. $I(i,t)$ is the indicator function that takes a value of 1 if an agent i is working on the market in period t.The same is true for all the agents in two-person two-earner households and for the agent 1 in the two-person one-earner household . For the stay-at-home agent $2k$ in a two-person one-earner household the hours can be allocated only between home production and leisure:

$$T = l_{2k,t} + h^h_{2k,t} \tag{6}$$

Households of two persons own assets and make investment decisions jointly. At period $t = 0$ each household is endowed with a^j_0 units of capital assets. I assume $a^j_0 \in (0,\infty)$. Capital depreciates at the rate δ. Capital assets of the household i move according to the following law:

$$a^i_{t+1} = a^i_t(1-\delta) + i^i_t \tag{7}$$

where i^i_t is investment of the household i and time t.

3.5 Home production and aggregate market technology

Any household also has access to the technology of home production. The home-produced good can be consumed only within the household and can not be invested. To simplify I assume that only labor ($h^h_{i,t}$) is used in home production, and that home production sector is not subject to any shocks. Labor displays diminishing returns. For one-person households the production of home good is given by:

$$c^h_{i,t} = f_h(h^h_{i,t}) \tag{8}$$

For both types of two-person households the amount of home production depends on home hours put in by both household members:

$$c^h_{j,t} = H(h^h_{1j,t}, h^h_{2j,t}) \tag{9}$$

where the function H is increasing in both arguments and strictly concave. Market goods are produced with a Cobb-Douglas production function that is subject to technology shock z_t:

$$Y_t = e^{z_t} {K_t}^{\alpha} {L_t}^{1-\alpha}, \qquad \alpha \in (0,1) \tag{10}$$

Technology shock follows the standard autocorrelation process with the autocorrelation parameter η and variance of the shocks ρ^2:

$$z_t = \eta z_{t-1} + \epsilon_t, \qquad \epsilon \sim N(0, \rho^2) \tag{11}$$

Market good can be consumed or invested. Note that investment good is produced only in the market:

$$Y_t = \int_i (c^m_{i,t} + i_{i,t}) di + \int_j (c^m_{j,t} + i_{j,t}) dj + \int_k (c^m_{k,t} + i_{k,t}) dk \tag{12}$$

4 Calibration

4.1 Functional forms

As in many recent aggregate labor supply studies (Rogerson and Wallenius, 2009; Prescott and Wallenius, 2012) the instantaneous utility function for the one-person household is an additive CES function in consumption and leisure:

$$u_{i,t} = \log c_{it} + \sigma \frac{l_{it}^{1-\gamma}}{1-\gamma} \tag{13}$$

The parameter $\sigma > 0$ specifies the relative value of leisure. The parameter $\gamma > 1$ determines the intertemporal (Frisch) elasticity of labor, which is given by $\frac{1}{\gamma}\frac{l_i}{h_i}$. For the two-person household the instantaneous utility function correspondingly becomes:

$$u_{i,t} = 2\log\frac{c_{j,t}}{1+\chi} + \sigma\frac{l_{1j,t}^{1-\gamma}}{1-\gamma} + \sigma\frac{l_{2j,t}^{1-\gamma}}{1-\gamma} \tag{14}$$

Composite consumption is a CES aggregation from market consumption and home-produced consumption:

$$C(c_{m,t}; c_{h,t}) = (a{c_{m,t}}^{e} + (1-a){c_{h,t}}^{e})^{1/e}, \qquad a \in (0,1), e \in (-\infty, 1) \tag{15}$$

The parameter a is the weight of market consumption consumption, while the parameter e reflects the elasticity of substitution between market and home-produced goods. This specification is standard in home production literature starting with the seminal work of Benhabib et al. (1991).

The home production technology has decreasing returns to scale in hours worked at home. I omit capital from home production function as the focus of the paper is on labor. For a one-person household i the home production function is:

$$c_i^h(h_{1,h,t}) = {h_{i,h,t}}^{1-\alpha_1} \tag{16}$$

For a two-person household j the home production function is separably additive in the home hours of the two household members:

$$c_j^h(h_{1j,h,t}, h_{2j,h,t}) = {h_{1j,h,t}}^{1-\alpha_1} + {h_{2j,h,t}}^{1-\alpha_1} \tag{17}$$

4.2 Household structure and individual productivities

The parameters governing the household structure (κ and ψ) are calibrated directly from the census data from Integrated Public Use Microdata Series on the U.S. (Ruggles et al., 2010). I used 5% samples from 1950, 1960, 1970, 1980, 1990, 2000 and 2010 to track the evolution of household structure (see 1). As in 2, I will use two sets of household structure parameters: corresponding to the household structure in 1950 and in 2000 in my simulation exercise.

I use earnings data from CPS (March supplement, 2010) to calibrate individual productivities. Individual productivities are calibrated to reflect hourly labor earnings (wages and salaries plus a fraction of business income, as in Diaz-Gimnez et al. (2011)). Weights for households with certain individual productivities are also assigned from CPS, and I take into account the actual household structure. Since the literature gives a lot of evidence on assortative mating in family formation (the most recent data exploration of assortative matching is in Greenwood et al. (2014), I take into account the joint distribution of primary and secondary earners in two-earner households. Hence, individual productivities within households are not independently distributed. There are five possible productivity values for one-earner households and 15 productivity value pairs for two-earner households.

4.3 Other parameters

A set of parameters β (discount factor), δ (depreciation rate), η (autocorrelation term for technology shock) and ρ (standard deviation of technology shock) are assigned their conventional values, as in Cooley and Prescott (1995).

Since the focus of this paper is the behavior of hours, main calibration targets are hours worked in the market and at home. I use American Time Use Survey (ATUS) data for 2003-2013 for the source of data on time use. ATUS is a nationally representative survey of non-institutionalized adult population (over 15 years). I define discretionary time as 24 hours less time spent on personal care activities. My broad definition of home work follows Ramey (2009) and includes four ATUS categories: household activities (housework), purchasing goods and services (less personal and medical care), caring for household members, and for non-household members. I define market work as time working, time spent on other work-related and income-generating activities. Time spent on travel related to work (for those who work) is the natural definition of the commuting cost τ.

I use micro estimates of Frisch labor supply elasticity as a target to calibrate γ, the parameter governing elasticity of labor in the model. Domeij and Floden (2006) give estimates of 0.2 to 0.6 for Frisch elasticity of labor supply of males. Estimates of female Frisch elasticity are typically higher, hence I will target Frisch elasticity of 0.5 for all individuals, a common choice in labor supply literature. The Frisch elasticity in the model economy depends also on the targeted hours worked and hours of leisure.

The parameter e determines the elasticity of substitution between market and home-produced goods. The estimates of this parameter in the literature range from 0.40 to 0.60 (Aguiar and Hurst, 2007; Nevo and Wong, 2014; Chang and Schorfheide, 2002). I choose the value of $e = 0.5$, which corresponds to the elasticity of substitution of 2. The coefficient α_1 in home production function is adopted from Gomme and Rupert (2007).

Two parameters left to calibrate - relative value of leisure σ, share of market good in consumption a, - are selected to match the average hours worked at the market and at home (3.32 and 3.25 hours a day according to ATUS).

Calibrated and chosen values of parameters are summarized in A.

5 Results and Discussion

The presence of two-earner households in the model generates new behavior patterns. The two-earner household may react to a negative technology shock by the exit of the least productive household member from the labor market or with a more rapid contraction in his or her hours (similar mechanism is described in Bornukova (2011) for a representative two-earner household) . As a result, the hours of the least productive household member decline more that those of the more productive, and the average productivity of labor supply from that household increases. If the proportion of the two-earner households is high enough, aggregate labor productivity may increase in response to negative technology shocks, rendering labor productivity counter-cyclical.

As the proportion of two-(or more) earner households increases from 34% (as in 1950) to 50.5% (as in 2000), the correlation of aggregate labor productivity with output changes from 0.28 to -0.46 in the model economy. This change is very similar to the one I observe in the U.S. economy over the similar periods (see Table 5).

Table 3: Cyclical behavior of aggregate labor productivity

Correlation of productivity with output

	1950:q1-1979:q4	1980:q1-2009:q4
The model	0.28	-0.46
The data	0.10	-0.27

Correlation of productivity with hours

	1950:q1-1979:q4	1980:q1-2009:q4
The model	-0.29	-0.72
The data	-0.38	-0.68

The negative correlation of productivity with hours worked also becomes more pronounced as a proportion of two-person households grows. While aggregate hours still drop in case of negative technology shock, productivity may increase not only through the decreasing marginal productivity, but also due to the fact that the cut in aggregate hours is mainly the cut in less productive hours.

The model economy captures well another change in the business cycle behavior in the U.S. - the increase in the relative volatility of hours. The volatility of hours relative to output has increased from 1.07 in 1950-1979 to 1.32 in 1980-2009. The corresponding change in the model is from 1.01 to 1.36. The increase in volatility of hours can also be attributed to changes in household structure: both the increase in the proportion of two-earner households and the increase in the proportion of single-adult households contribute to it. The labor supply of Type IV earner, a secondary earner in two-earner household is much more volatile than the labor supply of any other agent type in the model economy (see 5). When comparing two only earners in the households: Type I and Type II, one may see that the volatility of labor supply depends a lot on the household type of the earner. If the only earner is not the only person in the household, volatility of her labor supply is very low: her ability to substitute into home production is limited by the fact that another household member is already taking care of it. The only earner in the one-person household is more free to substitute into home production and leisure during bad times. The increase in the proportion of Type I and Type IV earners contributes to higher volatility of aggregate labor supply.

Table 4: Volatilities of labor supply by types in the model economy

		St. Dev
Type I	Earner in single-person household	2.91
Type II	Single earner in two-person household	0.31
Type III	Primary earner in two-earner household	1.65
Type IV	Secondary earner in two-earner household	4.83

Labor supply is aggregated by types. Based on decision rules in the 2000's structure of model economy. All variables are logged and detrended with HP filter

The complete set of the business cycle statistics of the model economy with two different household structures can be found in Appendix B.

6 Concluding Remarks

The increase in female labor force participation and the resulting change in household structure had important consequences for labor supply. I show that the increase in the proportion of the multiple-earner households may be the explanation behind the change in the cyclical behavior of productivity in the U.S. In recessions the multiple-earner household may adjust by the significant reduction of the market hours worked by the least productive member. If the share of multiple earner households is high enough, the aggregate labor productivity becomes counter-cyclical.

I build a model economy consisting of one- and two-earner households with agents different in productivity. I impose the household structure change in the model economy, which corresponds to the changes in the U.S. in 1950-2000. The behavior of the aggregate labor productivity in the model changes similarly to how it changed in the U.S. data. In particular the correlation between productivity and output becomes negative as the share of multiple-earner households increases.

I also show that the household structure and the role of the individual within the household have implications for the behavior of labor supply, in particular for its volatility. For example, secondary earners have higher labor supply volatility. Primary earners from the multiple-earner households are also more elastic than the only earners. As the share of multiple-earner households increases, the volatility of aggregate labor supply goes up. In the model economy the increase in the proportion of two-earner households (corresponding to the actual increase in the U.S. from 1950 to 2000) leads to the 30% increase in the volatility of aggregate hours, as in the data.

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A Calibrated Parameter Values

Parameter		Value	Calibration source or target
Relative value of leisure	σ	0.41	To match hours worked
Share of market good in consumption	a	0.12	To match hours worked
Frisch elasticity	γ	2.41	To match Frisch elasticity of 0.5
Labor share in home production	$1-\alpha_1$	0.62	Gomme and Rupert (2007)
Time endowment	T	1.00	normalized to 1
Commuting cost	τ	0.05	directly from the data
Substitution between c_m and c_h	e	0.50	
Discount factor	β	0.99	conventional value
Depreciation rate	δ	0.03	conventional value
Autocorrelation of technology shock	η	0.95	conventional value
St.d. of technology shock	ρ	0.01	conventional value
Capital share	α	0.36	conventional value

B Business Cycle Statistics of The Model Economies

Volatility relative to output, 1980:q1-2009:q4

	1950:q1-1979:q4		1980:q1-2009:q4	
	The data	The model	The data	The model
Consumption	0.81	0.88	0.80	0.85
Investment	4.50	3.80	5.25	4.62
Hours	1.07	1.01	1.32	1.36
Productivity	0.51	0.55	0.64	0.54

Correlations with output, 1980:q1-2009:q4

	1950:q1-1979:q4		1980:q1-2009:q4	
	The data	The model	The data	The model
Consumption	0.77	0.85	0.86	0.81
Investment	0.82	0.79	0.91	0.91
Hours	0.88	0.84	0.88	0.93
Productivity	0.10	0.28	-0.27	-0.46

Correlation of productivity with output

	1950:q1-1979:q4	1980:q1-2009:q4
The model	0.28	-0.46
The data	0.10	-0.27

Correlation of productivity with hours

	1950:q1-1979:q4	1980:q1-2009:q4
The model	-0.29	-0.72
The data	-0.38	-0.68

Belarusian Economic Growth Decomposition

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Abstract

Belarus experienced rapid economic growth in the 2000's, which abruptly came to a halt after 2008. We find that the major source of the growth was capital accumulation, while growth in total factor productivity (TFP) was modest. We also find that directed lending programs, initially designed to promote growth, cause capital misallocation and diminish aggregate TFP by 5-10 percent. Lack of productivity growth led to the loss of competitiveness on the international markets. Comparison of sectoral TFP in Belarus with Czech Republic and Sweden shows that comparative advantages of Belarus are concentrated in the natural-resource based industries, and TFP gap with Czech Republic is widening over time.

Keywords: Growth Accounting, Sectoral Productivity, Transition, Belarus, TFP, Directed Lending

JEL Classification: E25, O47, P27, D24

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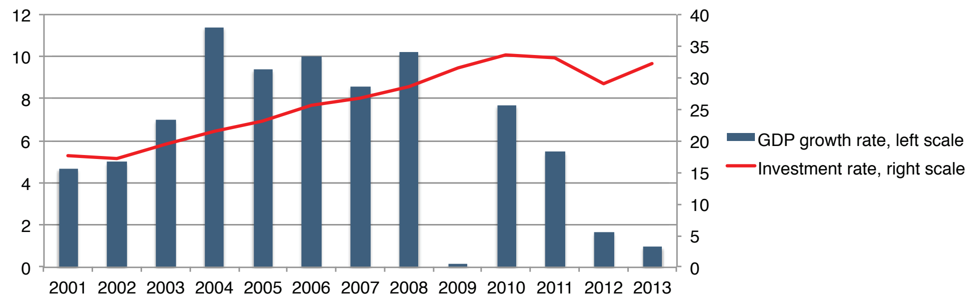
1 Introduction

Economic miracle - this is how many Belarusians were referring to the economic growth experience in the 2000s. Indeed, the growth rates were high and sometimes surpassed 10 percent per annum (see Figure 1). Growth was pro-poor (Haiduk and Chubrik, 2007), effectively reducing the poverty rate from 47 percent in 1999 to 5 percent in 2010 (World Bank, 2012). Even the recent crisis did not hurt Belarusian economy much: in 2009 the growth rate was close to zero, but still positive. Due to this steady growth in terms of PPP-converted GDP per capita in 2010 Belarus was lagging behind only the three Baltic states and the Russian Federation out of all the post-Soviet countries (Heston, Summers and Aten (2012)).

Figure 1: GDP growth rates and investment rates in Belarus, 2000-2012



The miraculous part is that Belarus differs strikingly from the other post-Soviet or transitional success stories. Unlike the Baltic states, it did not reform its economy and did not integrate with the EU. Belarus did not experience full-scale privatization, and many major enterprises remain in the state ownership or under state control. The government did not pay enough attention to the development of the private sector until recently. Belarus also failed to attract significant amounts of foreign investments. Foreign sources contributed only 3.48 percent of the total investment in 2001-2010. According to the overall index of transition reforms (Dell'Anno and Villa, 2013) Belarus is the penultimate among the other transition countries, outrunning only Turkmenistan. Unlike Russian Federation, Belarus does not have oil or gas, and potassium salts are the main and modest source of natural resource rents.

Despite the unique growth experience of Belarus, literature on growth in Belarus is scarce, to the best of our knowledge. Demidenko and Kuznetsov (2012) and World Bank (2012) used official capital estimates to perform growth accounting and found significant contributions of TFP to growth. We argue that the official statistics on capital are plagued with measurement problems, mostly due to high inflation rates (this is the case for many transitional countries, see, for example

Bessonov and Voskoboynikov, 2008). We reconstruct the capital series for 2006-2010 using the capital services approach. We use the reconstructed capital series both for the growth accounting procedure and to estimate and compare sectoral TFPs.

Our central finding is that capital accumulation was the main source of growth in 2006-2010 in Belarus. In this regard, Belarus follows the pattern of growth in the post-war USSR (Ofer, 1987). While many transitional and developing countries experience productivity growth in manufacturing, manufacturing TFP in Belarus was roughly stagnant. We also find that directed lending programs, initially designed to promote growth, cause capital misallocation and diminish aggregate TFP.

We compare sectoral TFPs in Belarus to those of another transition country, Czech Republic, and a developed country, Sweden. We find that Belarus is catching up to Sweden, but not as fast as Czech Republic. We also find that the TFP gap is more prominent in tradeable sector.

The paper proceeds as follows. In Section 2, we discuss our choice of methodology for the growth decomposition and TFP comparisons. Section 3 describes the data, and the procedure to reconstruct capital series. Section 4 presents the results of the growth accounting exercise for the economy of Belarus and its industries. Section 5 compares aggregate and sectoral productivity in Belarus, Czech Republic and Sweden. Section 6 concludes.

2 Methodology

Growth accounting and TFP comparisons are widespread elements in the literature on productivity analysis. However, the purposes and the methods of these exercises differ. By the criteria of computational methods and applicability of its results Islam (2001) aggregates existing strategies into three major approaches: (i) time-series (either in absolute or relative form); (ii) cross-section; (iii) panel regression. From the view of the applicability of results, cross-section and panel regression approaches are mainly intended for cross-country comparisons of TFP levels, growth rates, factors and sources of growth. This is done through bringing time-series data of different countries to a common denominator.

In our case, we do pursue the objective of incorporating Belarusian economy and its industries into inter-country comparisons, but along with in-country analysis. The latter assumes the comparison of productivity levels, dynamics and its sources among the industries of Belarusian economy as well. So, having both objectives in mind, we fall back upon time-series approach (both in absolute and relative form).

Absolute form of time-series approach consists of comparisons of TFP growth rates that are computed basing on standard growth accounting procedure (Young, 1995 is probably the best-known example, while Barro and Sala-i-Martin, 2004 offer a textbook treatment of this procedure). This approach mainly strives for dissecting the factors of output growth. It is expected to answer the question which share of growth can be contributed to inputs (labor, capital, and sometimes human capital) and which to the growth of productivity.

Relative form of time-series approach is mainly focused on the computations of TFP levels, which widens the boundaries of productivity analysis. TFP levels seem to be of particular interest from the view of studying the level of competitiveness. Moreover, TFP levels effectively supplement growth context by offering information on initial points and stages of growth.

2.1 Specification of production function

The specification of production function predefines differences in computational strategies within time-series approach.

According to the first criterion, the simplest option assumes the use of Cobb-Douglas production function. This computational strategy was initially introduced by Tinbergen (1942), and continues to be employed nowadays (IMF, 2010, World bank, 2012). Most frequently, growth accounting exercise based on the Cobb-Doulgas production function considers only the aggregate level, i.e. the entire economy. In this case, the shares of factor inputs usually are imposed (with the conventional values of 0.6 the share of labor, and 0.4 the share of capital). Another option is to compute the labor share from the income account. Independent on the source of the data, income share is constant through the entire sample and does not considerably affect the results of the estimation in terms of the growth rates.

More general and complicated specifications of production function are used when there is enough information to estimate the parameters of such specifications. Many authors use translog function to analyze production (Young, 1995; Christensen, Cummings and Jorgenson 1981). This specification of production function allows addressing the problems of aggregation. First, the issue of aggregation matters when the inputs are considered to be not homogenous, but a combination of different classes of sub-inputs. Second, the aggregation issue arises when the growth and its sources at the macro-level are aimed to be decomposed by industries of the economy. In both cases, proper weighting of the sub-elements matters for correct computation of productivity indicators.

Briefly, the basic advantage of translog production function may be interpreted as the opportunity to consider the shares of factor inputs as non-constant indicators that vary because of changing composition of correspondent aggregates. This advantage seems to be of particular importance when dealing with TFP levels. However, when undertaking analysis in terms of growth rates, one may mainly overcome the problem of aggregation by constructing a variable which is a Tornquist weighted average of its components. This growth accounting approach is mainly used in KLEMS studies (for instance, see Timmer et al., 2007 and 2010).

For our study, we need a computational approach that enables us: (i) to fulfill a growth accounting procedure, both at the aggregate level and at the level of industries; (ii) to compute and compare TFP levels of Belarusian economy and its industries with benchmark countries. Jorgensons methodology (Christensen et al., 1981, Jorgenson et al., 2005) seems to be the best option for joint and coherent analysis of both levels and growth rates. However, the lack of available data (in order to estimate the translog production function) is the obstacle to replicate this methodology in respect to Belarus.

Furthermore, there are two obstacles for feasible assessments of factor inputs shares in Belarusian economy. First, the assumption of factor markets competitiveness in Belarus is far from being fulfilled, which forms a gap between factors actual revenues and its marginal product. Second, a number of considerable inflation spikes during last two decades may determine a bias in correspondent estimations of factor inputs shares, as the latter assumes use of nominal parameters. Hence, in order to keep the conformity between the assessments in levels and growth rates we are to sacrifice the effect of changing shares of factor inputs. Through this, we resort to a most simple specification of production function, i.e. the Cobb-Douglas function, with a Hicks-neutral technical progress, (see Eq.1). We use this specification both on the level of the entire economy and for its individual branches.

$$Y_i = A_i K_i^{\alpha_i} L_i^{1-\alpha_i} \tag{1}$$

where Y is output, A is TFP, K and L are capital and labor, α is capital share, and i is the industry index. The absence of of the index i denotes the case of total economy.

2.2 Growth accounting procedure and computation of TFP level

From the Cobb-Douglas production function (1) we compute the level of TFP according to:

$$A_i = \frac{Y_i}{K_i^{\alpha_i} L_i^{1-\alpha_i}} \tag{2}$$

We must note that different measures of output either gross output or value added may enter production function (1) and TFP (2). The measure of the output determines the economic sense of the productivity (TFP) indicator. In our study, we constrain our analysis only to indicators based on value added. Using ones based on gross output according to (1) and (2) has little economic sense, since interpretation of the capital-labor total factor productivity based on gross output seems to be ambiguous. A meaningful measure of productivity based on gross output assumes that one more variable intermediate inputs (energy, materials, services and other supplies) should enter production function. However, adequate measurement of intermediate consumption in real terms, especially in industrial breakdown, is hardly possible for Belarus with a data set available.

Value added based indicators are the most popular in productivity studies. Nevertheless, rather frequently its economic sense is interpreted inaccurately, i.e. TFP level is expected to characterize technology only. However, this interpretation has plenty of caveats. First, the measure of productivity apart from technology also obviously includes measures of efficiency (understood as the distance between actual production point and production possibility frontier), economies of scale, capacity utilization, and measurement errors (OECD, 2001a and 2001b). Given that data on capacity utilization is mainly available (see Section 4.6), we can explicitly control the impact of the capacity utilization adjusting capital input by the correspondent rate. However, control of other components is hardly possible. Hence, we make simplifying assumptions that producers always operate at production possibility frontier and there are constant returns to scale, which means that TFP adjusted to the rate of capacity utilization (CU) may be treated as a characteristic of technology.

$$A_i = \frac{Y_i}{(K_i CU_i)^{\alpha_i} L_i^{1-\alpha_i}} \tag{3}$$

In terms of growth rates, we carry out growth accounting exercise according to:

$$\frac{\Delta A_i}{A_i} = \frac{\Delta Y_i}{Y_i} - \alpha_i \frac{\Delta K_i}{K_i} - \alpha_i \frac{\Delta CU_i}{CU_i} - (1-\alpha_i)\frac{\Delta L_i}{L_i} \tag{4}$$

2.2.1 Measuring allocative efficiency

Association of TFP with technology level is fully applicable (given the caveats mentioned above) in case when individual inputs and output are treated as integral ones, i.e. they cannot be disaggregated by components. We make such an assumption when dealing with industries of the economy. In other words, we treat each industry as an integral producer with its integral inputs, but not as the combination of output of individual firms with their individual inputs.

However, at the level of the entire economy such kind of disaggregation is possible. We consider total output and inputs as the combination of those of industries. Hence, TFP according to (3) in this case contains both characteristics of technology level and allocative efficiency. Allocative efficiency is broadly defined as the mix of inputs that produces a given quantity of output at minimum cost (Coelli et al., 2005). For our study, we elaborate the measure of allocative efficiency that is coherent with this definition.

First, we measure allocative efficiency in terms of output. For this, we solve an optimization (maximization) problem for output (see Equation 5), reallocating the one type of input among industries ceteris paribus, with a total amount of each input being given. Subsequently this problem is solved by reallocating capital or labor.

$$Y_k^* = \max_{K_i} \sum_{i=1}^{n} Y_i = \max_{K_i} \sum_{i=1}^{n} A_i (\bar{CU}_i K_i)^{\alpha_i} \bar{L}_i^{1-\alpha_i} \tag{5}$$

where $\bar{L}_i$ and $\bar{CU}_i$ are treated as fixed. We can define equivalently Y_l^* with maximization over L_i's holding $\bar{K}_i$ and $\bar{CU}_i$ fixed (given by the data).

Using the optimal output from (5), we can define the measure of allocative inefficiency relatively to the aggregate output Y. Losses in output due to misallocation of inputs are the most explicit measure. Hence, we define the measure of misallocation M associated with an input j (capital or labor) according to (6).

$$M_j = \frac{Y_j^* - Y}{Y} \tag{6}$$

Third, we can integrate the measure of allocative inefficiency with our TFP measurement (3). Aggregate TFP residual A may be decomposed for technology indicator T and allocative efficiency indicator AE_j:

$$A = T + AE_j \tag{7}$$

We assign zero values to allocative efficiency indicators in case when an input j is allocated in an optimal way:

$$AE_j = 0 \text{ iff } M_j = 0 \tag{8}$$

The optimal (in terms of allocation of input j) TFP level is defined according to:

$$A_j^* = \frac{Y_j^*}{(CU \cdot K)^{\alpha} L^{1-\alpha}} \tag{9}$$

Combining (7), (8) and (9) implies that optimal TFP level is identical to the technology level. Hence, in absolute terms we measure allocative efficiency associated with input j according to (10), and in growth rates according to (11).

$$AE_j = A - A_j^* \tag{10}$$

$$\frac{\Delta AE_j}{A} = \frac{\Delta A}{A} - \frac{\Delta A_j^*}{A} \tag{11}$$

2.3 International comparisons

TFP levels according to (3) are measured in national currency in constant prices of a particular year (2009 in our case). However, international comparisons require the indicators to be nominated in the same currency. Comparisons in international dollars seem to be the most reasonable for this purpose. However, instead of PPP concept that is more frequently used to internationalize the dollar in a number of studies, we resort to actual values of the exchange rate, which means that we are to use the index of real exchange rate of the national currency vs. US dollar. This choice allows to talk about the competitive advantages in international trade. According to this concept, for any nominal indicator X (nominated in national currency) that is the product of real quantity Q and price level P, its value in international dollar will be defined according to:

$$X_t^{b,int\$} = Q_t S_t \tag{12}$$

where $X_t^{b,int\$}$ is a variable measured in international dollars $int\$$ for a base period b, Q_t is a real quantity measured in dollar prices of the base period, S_t is the real exchange rate index between periods t and b (with S_b set to 1).

The growth rate of the indicator in respect to the base (zero) period is defined according to:

$$\frac{X_t^{b,int\$}}{X_b^{b,int\$}} = \frac{Q_t S_t}{Q_b} \tag{13}$$

Hence, we can rewrite (12) in a following form:

$$X_t^{b,int\$} = X_b^{b,int\$}\left(1+\frac{\Delta Q}{Q_b}\right)S_t \tag{14}$$

However, in respect to TFP this concept cannot be used straightforwardly, as TFP is not a primary indicator. It is computed through other primary indicators (inputs and output) non-linearly. Hence, applying (14) to (3), we get (15):

$$A_{t,i}^{b,int\$} = \frac{Y_{b,i}^{b,int\$}\left(1+\frac{\Delta Y_i}{Y_{b,i}}\right)}{\left(K_{b,i}^{b,int\$}\left(1+\frac{\Delta K_i}{K_{b,i}}\right)CU_{t,i}\right)^{\alpha_i} L_{t,i}^{1-\alpha_i}} S_t^{1-\alpha_i} \tag{15}$$

We use the indicators computed according to (15) as TFP comparison indicators that measure efficiency in 2009-year international dollars.

3 Data: sources, characteristics, generation procedures

3.1 The level of aggregation in dataset and sample periods

We carry out growth accounting procedure and make international comparisons of TFP on two levels of aggregation: (i) for the entire economy, (ii) for industries of the economy. For the entire economy this procedure is straightforward, as at the macro level Belarusian data for all the variables is available for 2005-2012. Breakdown by industries, however, is more problematic because of the shift in the system of classification of economic activity that was complete by the end of 2010. Before 2008, statistics was reported according to Soviet classification system (hereinafter, OKONH). This system was not comparable with any other international standard. In 2005, a shift to a new classification system (hereinafter, OKED) has been announced. OKED is the analogue of the statistical classification of economic activities in the European Community. OKED corresponds to version of NACE that was revised in 2002, that is usually treated as NACE Rev. 1.1 (hereinafter, NACE) with some minor adjustments to Belarusian context. In 2008-2010, which was an intermediary period, all the reports have been produced according to OKONH, but some of them simultaneously were produced according to OKED classification. Since 2011, only OKED classification is used in statistics. It should be emphasized that there is no direct concordance between economic activities in OKONH and OKED classifications. For broad economic activities (Section level according to OKED), Belstat has elaborated a generalized concordance table between OKONH and OKED. However, correct transformation of data from OKONH to OKED (and vice versa) according to this concordance table would require the data with a high level of disaggregation (up to 5 digits according to OKONH), which is not available. Hence, transformation of available data on value added, capital, and labor in OKONH classification to OKED classification is impossible.

We face a trade-off between the length of time period considered (historical data is available only in OKONH classification) and its closeness to present time (most recent data is available only in OKED classification). In order to keep both characteristics, at the level of industries we deal with two separate data samples that are formed according to different classification systems. The first sample is aimed to go back to historical values as long as possible and is classified according to OKONH. However, availability of the data (more precisely, data on capital; see Section 4.5 for more details) dictates a starting date for this sample, which is the year 2005. The upper bound is formed by data availability in OKONH classification, which is 2010. Hence, our first sample is 2005-2010 and it is organized by OKONH classification. Modest and flat inflation and absence of considerable structural shocks is an advantage of this period, which makes it a suitable representative period for Belarusian economy.

The second sample is aimed to provide evidence close to nowadays and is classified according to OKED. The starting point is formed by data availability (more precisely, labor; see Section 4.4 for more details) in OKED classification, which is the year 2010. The upper bound is formed by the availability of mostly fresh data, which is the year 2012. Hence, our second sample is 2010-2012 in OKED classification. OKED makes international comparisons possible. Furthermore, it provides most recent evidence about productivity.

3.2 The factor shares

Recent empirical literature (for example, Herrendorf and Valentinyi, 2008) suggests that factor shares differ substancially across industries. A standard approach to derive the share of factor inputs is to compute them directly in nominal terms using income-side disaggregation of value added. For our study, we exploit the system of input-output tables (more precisely, use tables in current prices) as the data source. The tables report the value added by each industry disaggregated by compensation of employees, gross profit, gross mixed income, and net taxes on production. Compensation of employees is the core of labor income in the economy, while gross profit and net taxes on production are associated with capital revenues. The standard problem is to allocate the mixed income between labor and capital revenues. For our exercise, we assign to each labor and capital 50 percent of gross mixed income. Hence, we treat the labor share as the relationship between the sum of compensation of employees and 50 percent of gross mixed income to value added, while the rest is associated with capital share (see Equations (16) and (17)).

$$\beta_i = \frac{W_i + 0.5MI_i}{VA_i} \tag{16}$$

where β_i is the labor share, W_i is the total employee compensation, MI_i is gross mixed income and VA_i is total value added in industry i.

$$\alpha_i = 1 - \beta_i \tag{17}$$

In case of Belarus, as shown above, two problems (lack of competitiveness at factor markets and huge inflation spikes) may hinder computation of factor shares according to (16) and (17). Furthermore, for individual industries a shift in the system of classification of economic activities during the period considered should be taken in mind, i.e. two separate data sets of factor inputs shares according to OKONH and OKED classification are to be generated. For OKONH classification we compute factor inputs shares basing on the data of 2005-2010. In these years inflation was modest and rather flat. Moreover, this period may be treated as the representative one for the structural relationships in the Belarusian economy. Hence, the estimates obtained on the data from this time period may be biased only because of lack of competitiveness.

For OKED classification, only the data for 2011 is available. However, use of this data leaves us little chances to assess correctly factor inputs shares for the OKED classification (i.e. since year 2011 and onward). First, one year is definitely not enough for reasonable assessment of factor shares. Second, this year (2011) stands out due to the currency crisis, huge inflation and correspondent adjustments in the national economy. Hence, factor inputs shares computed on 2011 data can hardly be considered as reasonable assessments of actual medium-term values. We resort again to data 2005-2010 according to OKONH classification and project it to OKED classification based on generalized concordance table (see Section 3.1) between two classifications. However, direct projection may be done only for the entire economy and for a few industries that are defined almost similarly in both classifications. If that a case, we consider the shares of labor in 2005-2010 to be the same for similar OKED industry. Further, we add an observation from 2011 and compute a labor share for an industry as the average of these 7 observations available. Otherwise, depending on the extent of concordance between industries according to OKED and OKONH, we assign weights to average of 2005-2010 and the value of 2011 years, and compute labor share for an industry as the correspondent weighted average. Obtained estimates for labor shares in industries are provided in Appendix A. For the entire economy, we get an average estimate of labor share in 2005-2010 of 0.595, which, however, goes down to 0.586 if the observation of 2011 is included. Nevertheless, in order to provide comparability with other studies (many of them set labor share to be 0.6, see, for example, Gomme and Rupert, 2007), we round up the value for the aggregate labor share to 0.6.

For a robustness check at the level of industries, we match our estimations with factor shares computed for Russia in Voskoboynikov (2012) (see Appendix A.2). This might be a good benchmark for comparison, as (i) characteristics of technologies in Belarus and Russia might be relatively close, given that just few industries have significantly changed technologies since the period of USSR; (ii) factor markets in Russia are much closer to the competitive stance rather than in Belarus (i.e. the actual revenues of correspondent factors are expected to be closer to their marginal product).

For the majority of industries, our estimates are close to those in Voskoboynikov (2012). There is, however, a significant difference among some essential industries: agriculture, trade and repair, and some manufacturing branches (chemicals, machinery and equipment, transport vehicles, etc.). However, for all this cases a reasonable justification dealing with technological issues may be found. For example, Belarusian manufacturing of transport vehicles mainly focuses on trucks, while the corresponding Russian industry focuses on cars. Belarusian chemical industry is extremely dependent on potash fertilizers, while the Russian chemical industry is more diversified.

3.3 Value added

The data source for the value added is the system of national accounts (hereinafter, SNA). Belarusian data according to SNA is reliable for a full period considered, as it is has been produced in strict coincidence with international standards[1].

SNA reports the value added both in current and constant prices. Within the period considered there was a shift in the base period for constant prices: the data for 2005-2009 is available in constant prices of 2005; the data for 2009-2012 is available in constant prices of 2009. In order to keep comparability between two our samples we recalculate value added in constant prices of 2005 into constant prices of 2009 (using correspondent growth rates). Hence, 2009 is the base period for prices in both our samples. In this manner we obtain value added in 2009 for the total economy and for industries of the economy according to OKONH.

However, this strategy does not work for obtaining the series of value added in sub-industries of the economy (more precisely, branches of the industrial sector[2]) according to OKONH. During the use of the OKONH classification, Belstat did not produce the estimates of value added for the branches of industrial sector using constant prices of a single year. For these branches the value added was calculated only in the prices of a previous year (for each year). We again use real growth rates for transforming available data to constant prices of 2009 year.

3.4 Labor input

We use the number of worked hours as the measure of labor input. This indicator is the product of an annual average number of employees and annual average number of hours worked per worker. These primary indicators are directly reported in labor statistics. For OKONH classification, they are available through 2005-2010, for OKED classification through 2010-2012.

3.5 Capital input

Among the factor inputs, just capital is usually characterized by high volatility that is consequent to volatility of investments. Hence, a proper approach to measuring capital input is vital for adequate computation of productivity and growth accounting exercise. However, many different measures of capital have been used in economic studies. The criteria on which they differ may be summarized as follows:

[1]For some other transition countries low quality of value added data, especially in industrial breakdown, is often a problem, as, say, double-deflation procedure is sometimes eliminated (see Voskoboynikov, 2012 for more details), and/or other drawbacks take place

[2]We use the term industrial sector in respect to the sector that according to OKONH classification contains OKED's manufacturing, production of electricity, gas, and water, and mining and quarrying.

1. Different concepts of capital: gross, net, or productive capital.
2. Different measurements: stock variable or flow variable.
3. Different sources of primary data: direct surveys of capital, investments data, firms' balance sheets, etc.
4. Different computational methods, techniques and assumptions.

For Belarus, feasible assessment of capital series is of particular importance, because the difference between available assessments is significant. The lower bound assessment for capital input is the official data. Belstat regularly reports real growth rates of capital according to gross concept. These growth rates display unnatural stability: during last two decades annual growth rate fluctuated around 2 percent. However, this dynamics of fixed assets does not match the dynamics of capital investments. The latter during last two decades (i) displayed rapid growth, (ii) this growth was rather volatile.

Bessonov and Voskoboynikov (2008) consider similar dynamics of official data in Russia. They argue that unnatural stability stems from biased investment deflators (they are overestimated) given the periods of hyperinflation in the beginning and late 90-s. Hence, the actual dynamics of capital input might be underestimated.

Rough estimates suggest that a core problem for Belarus is the same - biased investment deflators during the periods of high inflation. During the periods of relatively modest inflation, the biases are likely to exist as well, although they might not be so large. Given a number of specific features in the methodology of valuing capital in constant prices, the biases in investment deflator are accumulated and affect assessments for subsequent years. Hence, a U-shape form for the series of gross capital (in levels) is peculiar to Belarus (and to other countries that face such kind of problem).

Perpetual inventory method (hereinafter, PIM) is the most widely used method to recover the dynamics of capital stock. However, the use of PIM given biased deflators in general case cannot fully solve the problem of underestimation of growth rate of capital investments. Furthermore, depending on the primary data sources, estimates of capital may considerably differ under this computational method. For instance, Demidenko and Kuznetsov (2012) and World Bank (2012) apply PIM to data on inflows and outflows of capital. They obtain a raw series for the total economy that displays an extremely moderate growth rate (roughly 2 percent on average during 1995-2010). Hence, on the aggregate level they find that productivity was an engine of growth in Belarus. However, in IMF (2010), applying PIM to investments series, authors have obtained different results. Their capital input demonstrates much more powerful dynamics, which signals about capital-based growth during the period they consider (1995-2008).

Direct use of PIM given biased deflators seems to be more reasonable if the series has been recovered starting from the period after high inflation, i.e. after the biases in deflators are mostly huge. So the estimates begin with contemporary period and go back to the past. Such kind of a technique (we call it PIM-backward) allows avoiding accumulation of biases. Hence, during the period without biases the actual values (and correspondingly growth rates) would be recovered. However, if the biased observations enter the sample, correspondent values of capital stock (in levels) would be underestimated, which results in overestimation of the growth rates through the whole period. Given this caveat, we may consider assessments according to PIM-backward as a likely upper bound for capital stock.

Apart from the problem of bias, straightforward use of PIM tends to be improper option in respect to Belarusian growth accounting study due to a number of reasons. First, for productivity studies the concept of productive capital (rather than gross or net capital) is much more reasonable. OECD (2001b) argue that the value of the capital services produced by an asset (not the value of the asset itself) is the actual contribution of the capital input to production process. Hence, OECD (2001b and 2009) recommend to use a volume index of capital services (flow variable) as the measure of capital input that enters the production function. The concept of productive capital and capital services obviously assume measuring capital input by each type of asset individually and proper aggregation of these inputs afterwards. Direct use of PIM does not meet these demands. However, PIM technique may be implemented within capital services computational strategy.

Second, residential housing in Belarus is accounted in mixed historical prices. The last broad-based revaluation of residential housing has been made in 2000. After that it has been made only fragmentary by individual legal entities. A revaluation of assets on average for the economy for 2002-2010 amounted to 214 percent, while for residential housing it amounted only to 34.5 percent, although anecdotal evidence suggests that housing prices grew more rapidly than the prices of other capital assets. The share of housing investments was growing during the last decade and its share has exceeded 20 percent of total investments. Given that housing investment measures actual inflow of new capital of such kind, while this part of capital stock is considerably undervalued, it is to contribute huge distortions to the measure of total capital. Furthermore, at the level of industries, different approaches to accounting of residential housing may alter the results of the exercise. For example, a huge part of residential housing in the rural areas is assigned to agriculture, while in the urban areas majority of residential housing is assigned to real estate industry.

Third, some industries practice purchase and sale of capital assets at the secondary market. For some of them, purchases/sales at the secondary market amount up to 15 percent of capital flows. However, statistics of capital investments to be used in PIM does not capture these flows.

For our exercise we use the concept of productive capital (capital services) and combine data sources to eliminate the problems peculiar to Belarusian statistics. We use annual statistics of direct capital survey and flows of capital as the primary source of data[3]. First, this statistical report provides a needed level of breakdown (by groups of capital assets for each industry) for a productive capital/capital services concept. Second, the problem of bias in investment deflators is automatically eliminated here. This problem mostly arises because of incorrect aggregation of individual deflators in aggregate index. In this data source, we have disaggregated deflators (individually for each group of capital assets for each industry). Furthermore, these deflators are calculated based on actual revaluation of capital assets by firms rather than on registration of prices on capital goods. Third, we exclude residential housing in our capital measurement (which, unfortunately, implies elimination of real estate industry for our analysis, as residential housing is a major part of its capital stock) as there is no possibility to measure residential housing correctly. Available breakdown by groups of capital assets allows us doing so. Fourth, use of this data source allows capturing the flow of funds between industries.

However, some drawback of this data source should be emphasized. First, this field of statistics suffers from incomplete coverage. This statistical form is reported by large and medium commercial firms only. Majority of state-owned educational, health institutions and those that provide social services are not recognized as commercial in this context and do not report this statistical form. Hence, we have to exclude corresponding industries in our exercise. Furthermore, this data source does not include the capital flows of small business.

Second, some industries display large and persistent differences between the dynamics of newly introduced capital assets and dynamics of capital investments. This is of particular concern for building material manufacturing, chemical and petrochemical manufacturing, and wood, pulp and paper manufacturing according to OKONH classification; for mining and quarrying, manufacture of leather, manufacture of wood, manufacture of rubber and plastics products, manufacture of non-metallic mineral products, hotels and restaurants according to OKED classification. Traditionally, statistics on capital investments is considered to be the most reliable one. Although in some cases difference in two strands of statistics may be explained by time needed to install the new equipment, we, nevertheless, tend to consider investment flows to be more meaningful in the context of productivity measurement. Hence, we prefer to rely on capital investments data for total volumes, but to keep all other advantages that are provided by direct survey data source.

The algorithm of measuring capital input is as follows.

[3] Official name in Russian is "Otchet o nalichii I dvijenii osnovnyh sredstv I drugih oborotnyh aktyvov"

1. *Defining age-efficiency profile for each single asset and for cohorts of assets.*

   We follow recommendations of OECD (2009) to employ a profile with a constant percentage decline in efficiency for a cohort of assets (hereinafter, geometric pattern). OECD (2009) shows that there is empirical and theoretical evidence that supports use of geometric pattern in respect to combined age-efficiency/retirement profile for a cohort of assets. Furthermore, this kind of profile produces two huge benefits. First, there is no need to start with a profile for each single asset, as cohorts of assets may be treated straight away. Second, an identity between age-efficiency and age-price profile is kept for geometric pattern, which significantly simplifies the exercise. Thus, age-efficiency profile for the cohort of assets is defined according to:

   $$g_{t,i} = \frac{P^{\kappa}_{t,i}}{P^{\kappa}_{0,i}} = (1 - \delta^{\kappa}_{i}) \tag{18}$$

   where g is efficiency in standard efficiency units, p is the price of the group of assets, δ is a depreciation rate and κ refers to a group of capital assets. We use the averages of accounting depreciation rates for δ.

2. *Computing initial productive stock for each group of assets.*

   Identity between age-efficiency and age-price profiles results in identity between net and productive capital stocks. Hence, we straightforwardly use net stocks for each capital good for the earliest date available (in current prices). For OKONH sample a starting point is January 1st, 2005; for OKED sample it is January 1st, 2008.

3. *Computing capital flows data (in current prices).*

   We substitute the flows of newly introduced capital by each group of capital assets by corresponding capital investments according to:

   $$CF^{\kappa}_{t,i} = \frac{I_{t,i} I^{\kappa,DS}_{t,i}}{I^{DS}_{t,i}} \tag{19}$$

   where CF is a capital flow of newly introduced capital, I is capital investments, DS refers to direct survey of capital as a data source.

4. *Transforming initial stock and capital flows data to constant prices.*

   We employ individual deflators for each group of asset in each industry. The base period for constant prices is the first year available in each sample: for OKONH sample we transform data to annual average prices of 2005 year, for OKED to annual average prices of 2008 year.

5. *Computing productive stock for each group of asset in each industry through PIM.*

First, we compute productive stocks for the beginning of each year, according to (20):

$$K^{\kappa}_{t,i,bop} = K^{\kappa}_{0,i,bop}(1-\delta^{\kappa}_i)^t + \sum_{m=1}^{t-1} CF^{\kappa}_{m,i}(1-\delta^{\kappa}_i)^{(m-0.5)} \tag{20}$$

where K is the productive capital stock, *bop* refers to the beginning of the period.

Afterwards, we compute an annual average productive stock as simple average between two consecutive values according to:

$$K^{\kappa}_{t,i} = \frac{1}{2}\left(K^{\kappa}_{t,i,bop} + K^{\kappa}_{t+1,i,bop}\right) \tag{21}$$

6. *Computing real user cost.*

For each group of capital assets we compute real user cost RUC as the sum of real interest rate r and depreciation rate δ:

$$RUC^{\kappa}_i = r + \delta^{\kappa}_i \tag{22}$$

As a rule, interest rates within a particular industry are considered to be equal for any capital asset (this is secured by free management structure within an industry). However, the rates may differ among the industries reflecting different returns. While there is an ambiguity in the data on actual interest rates and returns by industries, we chose to equalize the rates among industries and set them equal to 5 percent. This might cause some distortions, especially when there is actually a huge diversity in real interest rates among industries. On the other hand, this assumption allows eliminating the problem of subsidized interest rates that are peculiar to Belarusian economy.

7. *Aggregating capital inputs by different groups of capital assets and computing the volume index of capital services.*

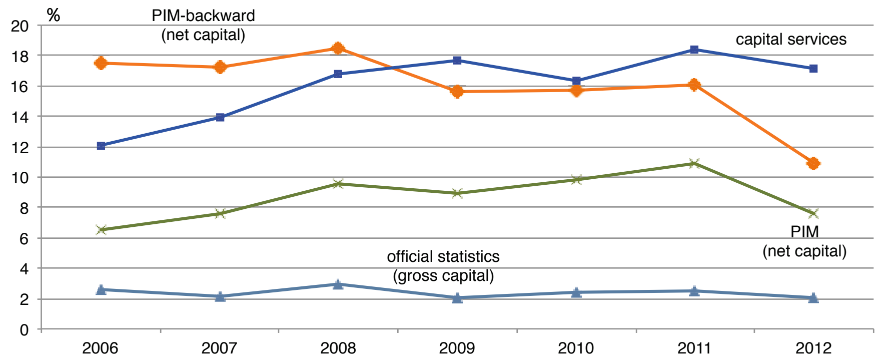
Real user costs are used as weights, and the volume index is obtained based on Tornqvist quantity index:

$$ICS_{t,i} = \Pi\left(\frac{K^{\kappa}_{t,i}}{K^{\kappa}_{t-1,i}}\right)^{\bar{\nu}^{\kappa}_i} \tag{23}$$

where $\bar{\nu}^{\kappa}_i = \frac{1}{2}(\nu^{\kappa}_{t,i} + \nu^{\kappa}_{t-1,i})$ and $\nu^{\kappa}_{t,i} = \frac{RUC^{\kappa}_i K^{\kappa}_{t,i}}{\sum_{\kappa} RUC^{\kappa}_i K^{\kappa}_{t,i}}$.

For the growth accounting exercise (4), we use (23) directly as the measure of capital input. However, for the computation of TFP levels (3) the variable that enters a production function needs some further development. Assigning the value of 100 to the base period (for each industry in each country) would undermine the contribution of initial levels of capital intensity into TFP, so there will be a considerable loss of information from the view of international comparison. Hence, we use a level of net capital stock for a base period (2009 year) as the starting value, and apply growth rates of capital services volume index to it in order to obtain the levels of capital input for other periods.

Figure 2: Growth rates of capital under different approaches



For a total economy, our basic measure for capital input (in comparison with measures from other approaches) is provided in Figure 2.

3.6 Capacity utilization

The main data source for capacity utilization is the survey of the firms prepared by the National bank of Belarus[4]. However, the Bank does not report capacity utilization rate for all the industries that are engaged to our study. For OKONH classification, the data on agriculture, communications, finance, credit, and insurance are absent. In respect to OKED specification, the data is missing for fishing, hotels and restaurants, financial activities, and branches of manufacturing. In case of missing data, we ground our assumptions on the available data for production of representative goods for a correspondent industry that are reported by Belstat. Another option is to link the dynamics of the industrial capacity utilization with those for the total economy, given either available or projected starting point.

[4]Official source name in Russian is 'Monitoring predpriyatiy realnogo sectora ekonomiki Respubliki Belarus'

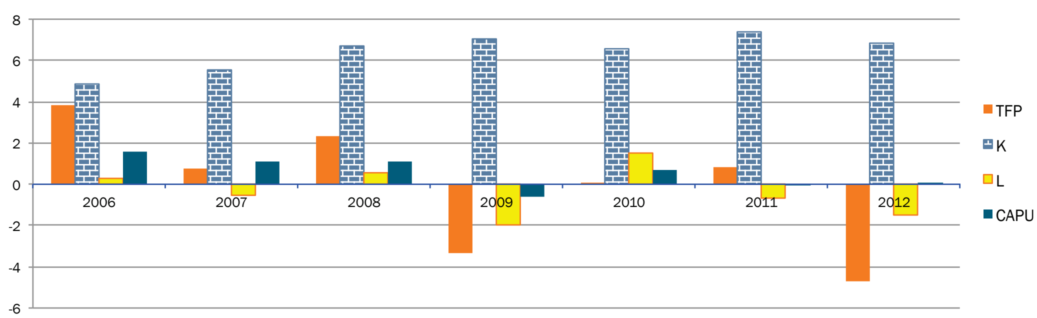
4 Sources and patterns of growth in Belarus

4.1 Growth accounting for the aggregate economy

Growth accounting exercise is treated as the procedure that gives a primary diagnostics of growth and visualize the contribution by each factor input and productivity. Macroeconomic basics assume that sustainable economic growth depends critically on the productivity growth. Other factor inputs have diminishing marginal returns. Hence, accumulation of factor inputs only may generate growth only until optimal (stationary) factor deepness has been achieved. Afterwards, only growth of productivity may generate sustainable growth.

Decomposition of growth for the entire Belarusian economy in 2006-2012 shows that the growth was driven by the accumulation of capital (see Figure 3).

Figure 3: Contributions of different factors and TFP to growth in Belarus, 2006-2012



At first sight, this diagnosis is not that surprising and disappointing. For instance, a capital-based growth is a widely accepted diagnosis for the countries that rely on catch-up strategy. For instance, Young (1995) demonstrated that accumulation of capital explains a huge part of growth in majority of Asian tigers through 1960-1990. However, in their case, rapid capital growth was accompanied by "not particularly low, but not extraordinary high productivity growth" (Young, 1995). However, in Belarusian case we must emphasize that capital was roughly the only engine of Belarusian growth (See Table 4.1).

This tremendous role of capital in Belarus worsens the diagnosis considerably. A country is expected to rely on extending productive capacities when the return on capital (marginal productivity of capital) is higher than its user cost. However, when the return on capital has reduced (due to accumulation of new capital), this strategy does not work anymore and additional injections of

Table 1: Average relative contributions to growth in value added, in percent

	2006-2010	2006-2012
Labor	-0.5	-5.3
Capital	81.5	98.3
Capacity Utilization	10.1	8.3
Productivity	9.0	-1.4
Gross Value Added	100.0	100.0

productivity are necessary to secure growth. Otherwise, growth rates will gradually decline to zero with further capital accumulation.

Hence, we argue that Belarusian growth during last years was not sustainable, as it was provided almost fully by capital input. Furthermore, we argue that a room for exploiting the strategy of capital extension has either exhausted, or at least is close to exhaustion: a rapid decrease in return on capital and its value approaching reasonable level of capital user cost signal about it (see Table 2). This view coincides with the evidence of sudden level shift in the growth rates by end of the last decade (see Figure 1).

Table 2: Marginal productivity of capital, in percent

	2005	2006	2007	2008	2009	2010	2011	2012
MPK^{*}	37.6	37.1	34.8	33	28.4	26.5	24.1	20.7
$MPK_{CU}{}^{**}$	52.1	49.4	45.1	41.6	36.3	33.4	30.3	26.1

* Return on total capital accumulated, computed by $MPK = \alpha\frac{Y}{K}$

** Return on total capital employed, computed by $MPK_{CU} = \alpha\frac{Y}{CU\cdot K}$

Finally, we argue that the lack of productivity gains is a major characteristic of recent growth in Belarus. While at the macro level productivity is strictly associated with the concept of national competitiveness, lack of productivity may be interpreted as poor national competitiveness. Furthermore, we admit that productivity growth should be the top priority for growth in Belarus.

4.2 Growth accounting for industries of the economy

The interest of growth accounting and productivity analysis at the levels of industries is threefold.

First, it answers the question whether the productivity path in the economy is the product of divergent paths of different industries, or it aggregates mostly monotonous paths by industries.

In the former case, poor gains in overall productivity may be associated with those in particular industries. The solution for this case might lie at the level of industrial policies and reallocation of resources only. However, if the latter case is on the agenda, the issue of systemic lack of productivity arises. It signals about unsatisfactory environment and vitalizes new growth enhancing incentives.

Second, productivity at the industrial level is traditionally treated as the measure of competitiveness. The ratio between productivity levels of two rivals (i.e. same industries) from different countries visualizes their relative (dis)advantages. This exercise assumes cross-country analysis (we produce it at Section 5). At the same time, comparison of productivity growth rates is worthwhile for in-country analysis, as it provides evidence about winners and losers in terms of progress in competitiveness. Furthermore, Levchenko and Zhang (2011) argue that there is a common trend that industries with a low initial level of relative productivity experience faster growth than those with a high initial level. This effect erases comparative advantages. While we do not have a benchmark for initial relative productivity level (it is possible to compare productivity levels only basing on OKED classification, i.e. since 2010), we make a distinction between high-grade and catch-up productivity growth in respect to in-country productivity level .

Third, the relationship of productivity growth rates between tradable and non-tradable sectors has implications for the development of real exchange rate. For instance, Harberger (1996) shows that if tradable sector is the leader in productivity growth, this is a likely precondition for the national currency to appreciate in real terms. However, if the productivity is driven by non-tradables, real exchange rate is expected to depreciate, ceteris paribus.

The results of growth accounting procedure for industries are reported in Appendix B.1. We can see that three sectors are distinct from an overall trend of capital-based growth: construction, communications, and finance and credit. In these sectors gains in productivity are responsible for roughly 50 percent of the observed growth. In overall, these sectors formed 16.4 percent of total value added in 2005-2010. Among them construction is of vital importance, because this sector is the largest - its weight was 10.3 percent - and it has displayed the most rapid productivity growth. However, there are some doubts on whether the progress in the computed TFP indicator actually was mainly caused by technological advances in the sector. One should take in mind that construction in Belarus (housing construction within it) is enormously dependent on directed lending programs. Directed lending generates additional artificial demand for the sector, which transforms into gains in TFP. But the other side of the coin is worsening productivity prospects in other sectors through a number of channels (Kruk and Haiduk, 2013). Hence, evidence in construction is not enough to argue that some huge industries follow the path different from the total economy.

Evidence of performance in communications and financial industry are better examples of productivity-based growth. However, because of their tiny weight in total value added these examples can hardly deny the conclusion that poor productivity performance is the systemic problem for the economy. Moreover, a huge part of productivity growth in communications may be explained by catch-up concept.

Table 3 reports the growth rates of productivity by industries of the economy given their initial relative positions in 2005. The development of TFP levels by industries does not display a bright

Table 3: Evolution of Industrial TFP Levels

	Relative TFP in 2005 (total economy=100)	Average TFP growth 2006-2010, percent
Construction	134.8	8.8
Communications	35	8.1
Finance, credit, insurance	89.4	7.7
Industrial sector	75.9	2.1
Other	49.4	6
Logging, wood, pulp and paper	109.2	5.1
Machinery and metal-working	142.1	3.9
Chemical and petrochemical	68.6	2
Fuel	16.3	1.9
Light industry	115.3	0.2
Ferrous metallurgy	62.1	-2.6
Food	100.8	-3.2
Building materials	118.1	-5.1
Electric power	50.6	-6.4
Agriculture	57.8	1.5
Trade and catering	145.4	-0.7
Transport	48	-0.7

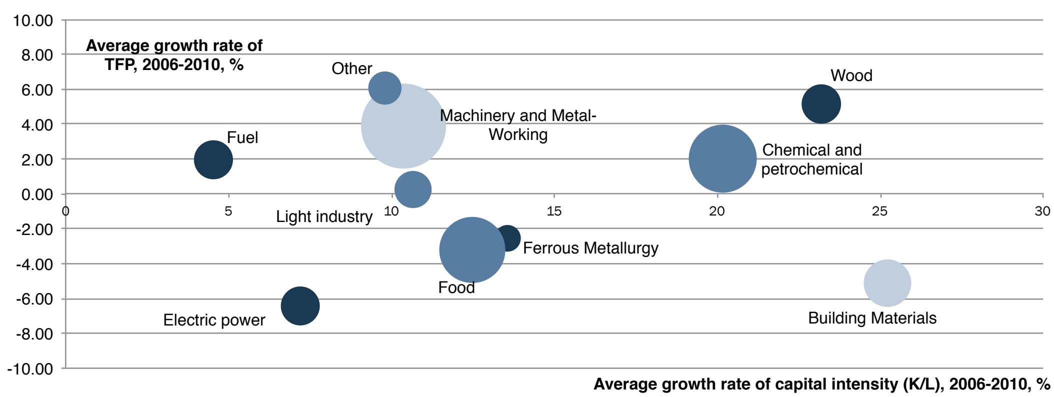
distinction depending on the starting positions. Hence, the period considered does not provide enough evidence that initially productivity-depressed industries experience a faster productivity growth in respect to their domestic rivals. There are some examples of a catch-up pattern (communications, financial industry), which, nevertheless, has not become a common trend.

In respect to the breakdown of industries by tradeability of their production, we also see no pure trend. On the one hand, communications, construction, and financial industry that are the leaders in productivity growth are definitely refer to production of non-tradeables. On the other hand, trade and catering and transport that also mainly refer to sectors producing non-tradables are losers in productivity ranking. So, in this field, we may only argue that the industries producing tradeables have not become strongly marked productivity growth leaders in the country. This implies that Belarus has not generated preconditions for appreciation of its exchange rate in real terms, while the latter is a common trend for majority of CEE transition countries. In other words, a medium-term trend of depreciation of real exchange rate reflects the problem of lack of competitiveness in production of tradeables.

4.3 Factor intensity and allocative efficiency

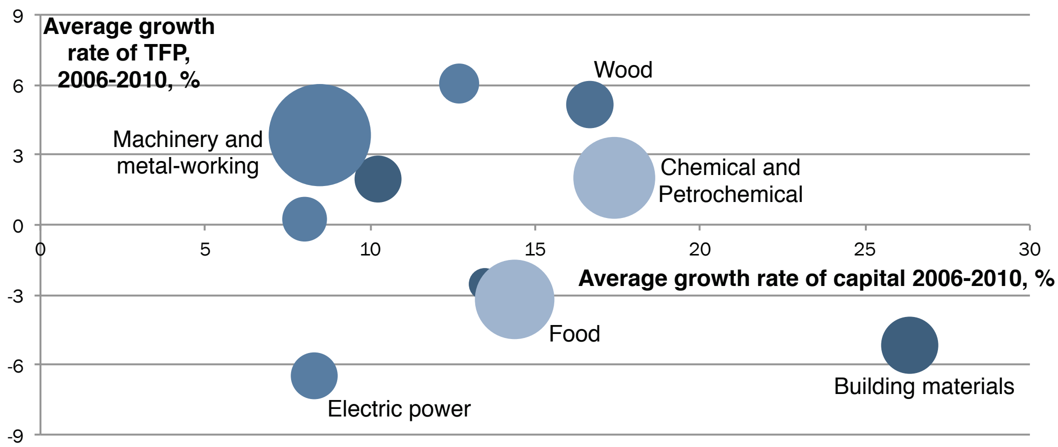
Productivity studies often implicitely expect that there is a strict relationship between capital intensity (i.e. the ratio K/L) and productivity both in terms of levels and growth rates. For instance, Wolff (1991) supports this expectation (mainly in terms of growth rates) for the developed countries. He argues that countries with higher capital/labor growth generally had higher TFP growth. In case of Belarus our data neither support nor directly disprove this hypothesis (see Figure 4).

Figure 4: Capital intensity growth and capital growth in Belarusian manufacturing, 2006-2012



This ambiguity in impact of capital intensity growth gives a rise to doubts in effectiveness of strategy of rapid capital accumulation. Wolff (1991) highlights numerous channels that can generate a positive relationship between capital growth and TFP growth. An embodiment effect, which assumes that at least some technological innovation is embodied in capital, tends to be the most powerful in this context. But our methodology of generating capital series (the embodiment effect is expected to have been captured already in the capital data) and specification of production function are to crowd out this effect from the accounting and to visualize disembodied technological progress only. However, there are other channels (perhaps less powerful) which are to secure, nevertheless, a positive relationship between capital growth and TFP growth. First, the introduction of new capital may lead to better organization, management, and the like (Wolff, 1991). Second, the learning-by-doing effect can positively affect productivity. Third, potential technological advance may stimulate capital formation, because the opportunity to modernize equipment promises a high rate of return to investment (Wolff, 1991). The last issue corresponds to a proper allocation of inputs, as the inputs are to move to those industries that experience higher returns.

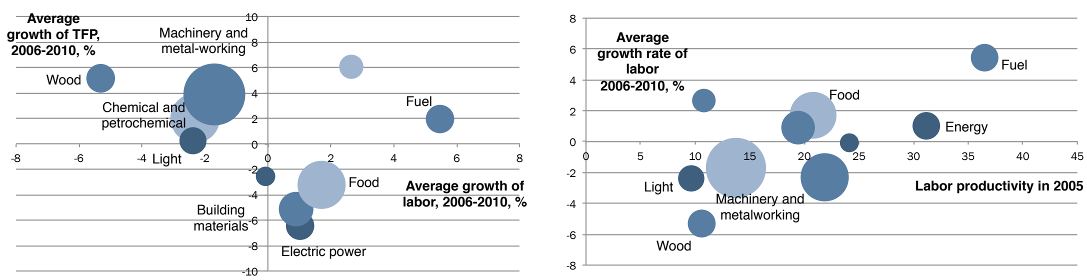
Figure 5: Capital growth and TFP growth in Belarusian manufacturing, 2006-2012



Belarusian data suggests negative relationship between rates of capital accumulation and TFP growth (see Figure 5). A negative relationship implies that more capital leads to less efficiency, which tends to have little sense at the first sight. However, it does not look contradictory in light of Belarusian practice of directed lending (when the resources are allocated administratively to the industries basing on criteria other than returns on capital). For instance, Kruk and Haiduk (2013) emphasize a number of channels that determine less efficiency because of capital accumulation through directed lending procedures. They argue that allocative inefficiency (the capital comes to industries with low returns and distort incentives of the producers that obtain directed loans), liquidity shortage effect (underinvestment by productive firms), and financial intermediation inefficiency (savings rate is going to be damaged along with higher credit spreads) cause a trade-off between capital accumulation and TFP gains. A negative relationship between capital growth and TFP growth in Belarus provides additional evidence about existing trade-off between them. Furthermore, this evidence emphasizes the problem of improper allocation of capital, which leaves a huge room for TFP gains through better allocation.

A relationship between labor growth and TFP growth is also expected to be positive. Here the proper allocation prevails: growth in productivity is to raise labor productivity, which will attract more labor. Figure 6.A displays an ambiguous relationship: a group of industries exhibit clear positive relationship between TFP and labor growth (fuel, food, electrical energy, building materials), while another group (machinery, woodworking, chemical production, and light industry) demonstrated gains in productivity vs. reduction of labor inputs. These two distinctive trends push us to account for the initial level of labor productivity, as a negative relationship is expected in case when the second group reduced labor given its initial excessive level. Figure 6.B presents a positive relationship between the level of labor productivity in 2005 and labor growth in 2006-2010, which supports the hypothesis of eliminating excessive employment. Industries which increased TFP and lost labor at the same time had low initial labor productivity.

Figure 6: Reallocation of labor in Belarusian manufacturing



A: Labor growth and TFP growth

B: Labor growth and labor productivity

Overall, we admit that the relationship between labor growth and TFP growth provides evidence that there is some room for efficiency gains due to proper allocation of labor, although this room seems to be much less than in respect to capital.

The issue of proper allocation seems to be of huge importance for Belarus. For a robustness check and in order to obtain additional measures of allocative inefficiency we assess correspondent losses in output (according to Eq.6) and contribution of allocative efficiency into TFP dynamics (according to Eq.11). We do this exercise for both samples OKONH 2005-2010, and OKED 2010-2012; and for three groups of industries: all industries with available data, for industrial sector (in OKED classification industrial sector is defined as the sum of mining and quarrying, manufacturing, and production and distribution of electricity, gas, and water), and for branches of manufacturing only. In first two cases (for all industries and for industrial sector) we impose an additional restriction that an input inflow/outflow from an industry should not excess 40 percent of its actual level. The measurements of inefficiency in capital allocation are provided in Table 4, sections A and B.

Table 4: The measures of capital and labor allocation inefficiency

A. Capital allocation, 2006-2010 (OKONH sample)

	2006			2007			2008			2009			2010		
	T	IS	M	T	IS	M	T	IS	M	T	IS	M	T	IS	M
M_k	7.9	5.1	8.3	8.1	5	8.2	8.4	4.2	4.7	9	5.7	4.7	8.8	5.2	5.0
$\Delta A/A$	7.7	4.7	5.4	5.5	2.7	3.1	7.8	8.3	7.9	−3	−7	−6.1	3.5	3.5	4.1
$\Delta AE_k/A$	−1.1	0.4	1.7	−0.6	0	−0.1	−1	0.5	3.1	−0.4	−1.2	0.3	−0.1	0.3	−0.6

B. Capital allocation, 2010-2012 (OKED sample)

	2010			2011			2012		
	T	IS	M	T	IS	M	T	IS	M
M_k	10.5	8.5	6.0	10.8	9.1	5.5	10.8	10.1	8.0
$\Delta A/A$				3.4	−2.2	−1.0	−3.2	−2.8	−3.2
$\Delta AE_k/A$				−0.7	−0.6	0.4	0.0	−0.9	−2.3

C. Labor allocation, 2006-2010 (OKONH sample)

	2006			2007			2008			2009			2010		
	T	IS	M	T	IS	M	T	IS	M	T	IS	M	T	IS	M
M_l	2.8	1.7	2.1	2.7	1.8	2.3	2.6	1.7	2.3	2.8	1.4	1.9	3.1	1.7	2.2
$\Delta A/A$	7.7	4.7	5.4	5.5	2.7	3.1	7.8	8.3	7.9	−3	−7	−6.1	3.5	3.5	4.1
$\Delta AE_l/A$	−0.1	−0.1	−0.3	−0.1	−0.2	−0.3	−0.1	0	−0.1	−0.2	0.4	0.5	−0.4	−0.3	−0.4

D. Labor allocation, 2010-2012 (OKED sample)

	2010			2011			2012		
	T	IS	M	T	IS	M	T	IS	M
M_l	2.8	1.4	1.5	3	1.3	1	2.8	1.6	1.4
$\Delta A/A$				3.4	−2.2	−1	−3.2	−2.8	−3.2
$\Delta AE_l/A$				−0.2	0.1	0.4	0.2	−0.3	−0.3

Notes: T denotes to total economy (i.e. all industries for which the data is available), IS industrial sector, M manufacturing. M_k is computed according to (6) and measures output losses (as percentage from actual output) due to misallocation, $\Delta AE_k/A$ is computed according to (11) and measures contribution of allocative efficiency into TFP growth in percentage points.

Overall, the data provides evidence that there is a huge room for efficiency increase just due to proper reallocation of capital: it may secure a single-shot increase of TFP and correspondingly output by from roughly 5 up to 10 percent of the actual level (depending on the set of industries considered). Estimations in respect to different set of industries provide evidence that inefficiency in manufacturing is lower than in a broader set of industries. The latter mainly stems from agriculture and electrical energy that are two most severe sources of misallocation. Furthermore, different sets of branches exhibit different evolution of inefficiencies over time and the increase in total inefficiency is again mainly associated with agriculture and electrical energy. Finally, during a period of high uncertainty and inflation (2011-2012), the volatility of inefficiency indicators increased, which reflects unstable environment at the financial markets.

The results of the similar exercise in respect to labor allocation suggests higher relative (i.e. in respect to capital market) effectiveness of labor market (see Table 4 section C and D). Losses in output due to misallocation of labor are systematically lower than those of capital. Furthermore, a difference in levels and growth rates is not so sensitive to the set of branches considered. Although total economy exhibits higher inefficiency (that again mainly stems from agriculture) than either the industrial sector or manufacturing, the gap is not that huge as in case of capital. A remarkable notice about labor allocation efficiency: it tends to improve during crisis years (2009 and 2011), while during fat years it mainly worsens.

5 Comparing Belarus to its neighbors: productivity in Czech Republic and Sweden

To understand how the performance of the Belarusian economy differs from the performance of other countries form the region, we compare it to the economies of Czech Republic and Sweden. Czech Republic is a leader of transition (Kornai, 2006; Winiecki, 2003) with one of the highest GDP per capita in the Central-European region. It is also comparable to Belarus in population, size, and (lack of) natural resources. We will compare both the growth patterns in Belarus and Czech Republic, and the TFP levels of the corresponding industries and sectors of economy.

Sweden represents a technological frontier in our study. Sweden, like Belarus, is a socially oriented state (although the countries have different approaches to social policies), which imposes similar technological constraints on the production. Sweden also resembles Belarus in size and population. While little insight can be gained from comparing growth patterns of a developed economy like Sweden to developing economy of Belarus, we can compare TFP levels across countries to estimate how far Belarus is from the world technology frontier and what is the potential for the catch-up growth.

In this section we use the sectoral and aggregate data on real investments, labor input, capacity utilization and real value added from Eurostat. We reconstruct capital series from 2000 to 2011 for both countries with the perpetual inventory method in its traditional form. We use EU-KLEMS capital estimates (O'Mahony and Timmer, 2009) as the initial point for capital. We assume the depreciation rate is uniform across sectors and equal to 0.05.

Apart from the difference in the concept of capital, there is one more important difference between Belarusian and Czech/Swedish capital series: in Belarusian data investment and capital estimates are net of taxes on products, while European statistics provides gross capital formation series which include all taxes. We estimate that on average Belarusian capital series would be around 8 percent higher under the use of European statistical procedures. This discrepancy has no effect for the growth accounting results. However, it may affect our estimates of TFP differences.

5.1 Sources of growth in Czech Republic

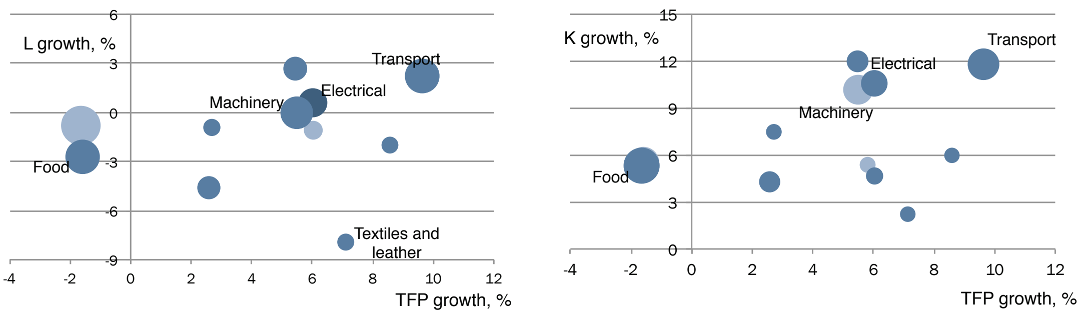
Czech Republic has started its transition earlier than Belarus. It is also more developed: according to the Penn World Table data (Heston, Summers and Aten, 2012), in 1995 PPP-adjusted GDP per capita in Czech Republic was 3 times higher than in Belarus. The income gap declined over time due to higher growth rates in Belarus. In 2010 GDP per capita (PPP-adjusted) in Czech Republic was only 73 percent higher than in Belarus.

The sources of growth in Belarus and in Czech Republic also differ. Over the period of 2001-2010 the average annual growth rate in Czech Republic was 3.6 percent (compared to 7.4 percent in Belarus over the same period). Growth in aggregate productivity contributed 1.91 percentage points out of 3.6 percent in Czech economy, while in Belarus capital accumulation was the major driver of growth.

Capacity utilization also played important role for growth in Czech Republic. Over our period of interest, 2000-2010, capacity utilization in manufacturing grew from 81.6 percent in 2000 up to 89.1 percent in 2007. Afterwards, however, capacity utilization dived to 76.3 percent over the Great Recession.

Appendices C.1 and C.2 present the results of growth accounting exercise for the major sectors and industries of the Czech economy in 2001-2010. We took into account capacity utilization for the branches of manufacturing. Manufacturing and trade, two larges sectors of the economy, were the major drivers of growth. But the sources of growth in those sectors differ: TFP was contributing to the growth in manufacturing, while trade grew mainly due to capital accumulation in this period.

Figure 7: Reallocation of capital and labor among industries of Czech manufacturing



A: Labor reallocation B: Capital reallocation

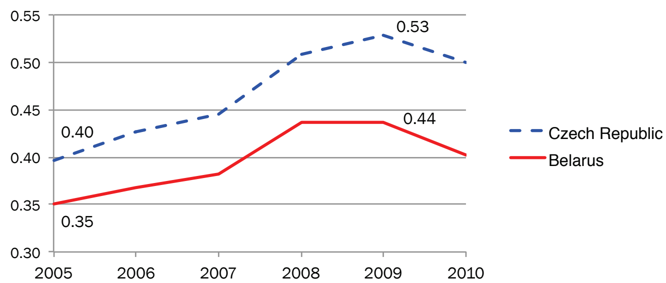
In all the growing branches of manufacturing, like machinery, production of electrical equipment and transport vehicles, growth in total factor productivity was the main driver of growth. This is in line with the stylized fact that productivity growth is usually higher in the tradable sector.

As figure 7 shows, within manufacturing sector factors of production reallocated effectively to the industries with higher TFP growth. Growing industries like transport equipment manufacturing, machinery or electrical equipment manufacturing experienced increases in TFP, and also attracted capital and labor from other industries. This fact may suggest that factor markets in Czech Republic function more efficiently than in Belarus, where there is no positive relationship between TFP growth and growth in factors of production.

5.2 Comparisons of aggregate productivity levels: where is the Belarusian comparative advantage?

We used TFP residuals to compare productivity among the sectors and industries in Belarus, Czech Republic and Sweden. To convert the measures of output (value added) and capital into U.S. dollars, we used the real effective exchange rates (REER) as estimated by the central banks of the corresponding countries. REER-converted measures of TFP (according to Eq.15) reflect the competitiveness of the sector/industry in international trade. Any direct TFP comparisons are only indicative of the relative performance. Differences in the statistical methods, in particular in construction and quality of capital series may make them not directly comparable. However, since we can assume that the possible biases from the data are uniformly distributed across sectors and over time, relative TFP measures and their evolution over time can shed some light on the economic growth patterns in Belarus.

Figure 8: Catching up: Aggregate TFP in Belarus and Czech Republic relative to Sweden



We already know that TFP was growing relatively slower in Belarus than in Czech Republic, and Figure 8 confirms it once again. We have chosen Sweden as a benchmark developed country and compare aggregate Czech and Belarusian TFP levels to it. Czech Republic started out with the relatively higher level of TFP, but despite that it converged to Swedish level faster. Belarus managed to close only 9 percentage points of the gap over 2005-2009, while Czech Republic diminished the gap by 13 percentage points. As a result, the gap between the two transition countries increased.

Table 5 lists the industries and sectors of Belarus economy which are the most and the least competitive in the relative TFP sence. Non-tradable sectors, namely trade and finance, have the smallest TFP differences with the developed Sweden. This finding is in agreement with Balassa-Samuelson argument (Balassa, 1964; Samuelson, 1964) and recent empirical findings by Herrendorf and Valentinyi (2012). Belarusian trade sector, both retail and wholesale, benefits from price-scissor practices in many domestic industries. Wholesale trade also often appropriates the benefits of low oil prices (along with the chemical industry) and other preferences from Russia. Food manufacturing is another benefactor of price-scissor practices in agriculture (UNDP, 2011). Demand-stimulating policies and relatively high real exchange rate also add to the relative success of non-tradable and consumption sectors like trade, finance or food manufacturing. Coincidentally, trade and finance are also the sectors with higher than average share of private ownership, which may also contribute to higher TFP (see evidence on higher TFP in Belarusian private manufacturing in Favaro, Smits and Bakanova, 2012).

Resource-based industries comprise another group of winners. The main natural resource in Belarus, potassium, gained the place in the champions list both for the mining and the chemical manufacturing sector.

Many of the industries "inherited" by Belarus from the Soviet Union end up on the list of underachievers. Machinery, electrical and transport manufacturing are among the main exporting

Table 5: TFP champions and underachievers in Belarus relatively to Czech Republic and Sweden

	Relative to	
	Czech Republic	**Sweden**
Champions		
Trade and repair	2.12	1.09
Chemicals	2.02	-
Mining and quarrying	1.35	1.01
Food, beverages and tobacco	1.24	0.57
Basic metals	1.20	0.61
Financial activities	1.15	0.81
Underachievers		
Textiles and leather	0.73	0.27
Machinery and equipment	0.71	0.34
Wood	0.68	0.29
Electrical, electronic and optical equipment	0.65	0.22
Transport vehicles and equipment	0.63	0.58
Electricity, gas and water	0.25	0.27

2010 TFP residuals, REER-converted. Belarusian TFP values (capital services approach) relative to the corresponding sector or industry of Czech and Swedish economies.

sectors, and given the low relative TFP levels, it is not surprising that these exports are not successful in the EU and are deteriorating in Russia. Textiles and wood manufacturing are two industries which have become proverbial of the failing state management and modernization efforts in Belarus. Government-controlled sector of the provision of electricity, gas and water is notoriously inefficient and suffers from the price controls by the government and non-clear subsidizing schemes (World Bank, 2013).

See Appendix D for detailed report of REER-converted TFP levels in 2010.

6 Conclusions

Over the period of 2006-2010, capital accumulation was the major source of economic growth in Belarus. It explains over three fourths of the average annual growth rate of 7.53 percent in value added. Increase in capacity utilization also contributed to the growth more than increase in TFP, which accunts for only one tenth of the growth. This extensive growth reminds of the Soviet growth pattern and has already led to expected economic slowdown. Further capital accumulation and increases in the capacity utilization will have limited effect on growth.

More capital, however, is not always a good thing. At the sectoral level, industries and sectors with relatively low capital-output ratio, along with a high level of competitiveness and involvement of foreign capital, like trade and finance, tend to be more productive. The only exception here is construction, which benefited from the directed lending policies of the government.

The slow growth of aggregate productivity is aggravated by the misallocation of capital. Capital accumulation does not accompany the growth of productivity for the majority of industries. On the contrary, for some industries excessive capital accumulation might be an obstacle (or a substitute) for productivity growth. Because of misallocation of capital across sectors, Belarus loses about 5 to 10 percent of its actual output. More flexibility on the capital market and less directed lending practices will result in better capital allocation and provide considerable single-shot increase in output.

In the context of long-term growth strategy, a trade-off between capital accumulation and TFP growth gives a rise to doubts about the efficiency and prospects of capital-driven TFP progress. At the same time, there is a huge room for disembodied TFP growth, for example, by building a system of proper incentives, effective regulation and efficient allocation of resources. Moreover, the latter strategy seems to be less costly in terms of short-run macroeconomic disturbances and financial expenses.

Labor markets are more efficient in allocation. A significant number of industries increase their productivity due to elimination of excessive labor employment. Positive association between productivity growth and labor input is peculiar only to finance, construction and fuel industry.

Despite high aggregate growth rates, Belarus is lagging behind other transitional countries in aggregate productivity. In particular, the productivity gap with Czech Republic is not diminishing over time. The lag in TFP resulted in the crisis of the comparative advantage, causing systemic trade deficits and, in particular, currency crisis of 2011. Indeed, the Belarusian productivity advantages are concentrated either in the non-tradable sectors like trade and finance, or natural-resource based like chemical manufacturing or mining.

To escape the trap of slow economic growth and poor international competitiveness, Belarus should concentrate on policies promoting TFP growth. The misallocation of capital, for example, represents an untapped resource of growth through reallocation of resources to the more efficient industries and firms. High TFP gap in comparison to the developed Sweden suggests there is room for growth through technology adoption. Policies aimed at promoting competitiveness and better state-owned enterprise management (in particular, through privatization) will create incentives and conditions for technology adoption.

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A Factor shares

A.1 Factor shares according to OKONH classification

Industry code	Industry name	Labor share (average 2005-2010)
10000	Industrial sector	0.511
11100	Electric power	0.401
11200	Fuel	0.181
12100	Ferrous metallurgy	0.416
13000	Chemical and petrochemical manufacturing	0.371
14000	Machinery and metal-working	0.732
15000	Logging, woodworking, pulp and paper	0.691
16100	Building materials	0.473
17000	Light industry	0.752
18000	Food	0.459
-	Other manufacturing	0.525
20000	Agriculture	0.626
60000	Construction	0.594
51000	Transport	0.429
52000	Communications	0.357
70000	Trade and catering	0.443
96000	Finance, credit, insurance	0.402

A.2 Factor shares according to OKED classification

Industry code	Industry name	Estimated labor share	Labor share in Vokoboynikov, 2012	Difference (4)-(3)
1	2	3	4	5
A	Agriculture, hunting and forestry	0.621	0.843	0.22
B	Fishing and fish farming	0.561	–	0.04
C	Mining and quarrying	0.224	0.156	−0.07
D	Manufacturing, including	0.459	0.552	0.09
DA	Food, beverages, and tobacco	0.451	0.444	−0.01
DB	Textiles	0.717	0.715	0.00
DC	Leather and footwear	0.475	0.696	0.22
DD	Wood	0.677	0.553	−0.12
DE	Pulp and paper. Publishing	0.537	0.623	0.09
DF	Coke, petroleum and nuclear	0.175	0.214	0.04
DG	Chemicals	0.243	0.493	0.25
DH	Rubber and plastics	0.431	0.510	0.08
DI	Non-metallic mineral products	0.485	0.622	0.14
DJ	Basic metals	0.423	0.602	0.18
DK	Machinery and equipment	0.587	0.774	0.19
DL	Electrical and optical equipment	0.591	0.769	0.18
DM	Transport vehicles and equipment	0.463	0.812	0.35
DN	other industries	0.518	0.658	0.14
E	Electricity, gas and water	0.447	0.404	−0.04
F	Construction	0.606	0.699	0.09
G	Trade and repair	0.369	0.550	0.18
H	Hotels and restaurants	0.655	0.677	0.02
I	Transport and communications	0.448	0.580	0.13
J	Financial activities	0.383	0.381	0.00

B Sources of growth in Belarus, 2006-2010

B.1 Growth accounting for Belarusian industries

In percent. Annual averages for 2006-2010, accounting for capacity utilization.

	Industry's share*	Growth rate	Contribultions of			
			TFP	K	L	Capacity
Total (based on gross VA)	100.0	7.53	0.67	6.13	−0.04	0.76
Industrial sector	29.6	8.73	2.07	6.38	−0.49	0.78
Agriculture	9.0	2.50	1.25	4.74	−1.56	0.03
Construction	10.3	19.38	9.58	6.15	2.75	0.90
Transport	9.8	1.52	−0.73	1.26	−0.20	1.18
Communications	2.3	16.65	8.62	7.20	−0.39	1.22
Trade and catering	12.3	10.48	−1.01	10.13	0.57	0.80
Material supply	0.4	−3.84	-	-	-	-
Health care	3.9	2.43	-	-	-	-
Education	5.3	−0.02	-	-	-	-
Culture	0.6	4.47	-	-	-	-
Science	0.7	−1.74	-	-	-	-
Finance, credit, insurance	3.9	17.25	8.42	6.54	1.15	1.14
Other	12.0	-	-	-	-	-
Industrial branches:						
Industrial sector	29.6	8.73	2.07	6.38	−0.49	0.78
Agriculture	9.0	2.50	1.25	4.74	−1.56	0.03
Construction	10.3	19.38	9.58	6.15	2.75	0.90
Transport	9.8	1.52	−0.73	1.26	−0.20	1.18
Communications	2.3	16.65	8.62	7.20	−0.39	1.22
Trade and catering	12.3	10.48	−1.01	10.13	0.57	0.80
Material supply	0.4	−3.84	-	-	-	-
Health care	3.9	2.43	-	-	-	-
Education	5.3	−0.02	-	-	-	-
Culture	0.6	4.47	-	-	-	-
Science	0.7	−1.74	-	-	-	-
Finance, credit, insurance	3.9	17.25	8.42	6.54	1.15	1.14
Other	12.0	-	-	-	-	-

*Shares for the industries are computed as averages for 2005-2010

C Sources of growth in Czech Republic

C.1 Growth accounting for the sectors of Czech economy

	Industry's share	Growth rate	Contribultions of TFP	K	L
Total	100.00	3.60	1.91	1.68	−0.05
Agriculture	2.67	3.90	−2.65	1.30	−2.49
Mining and quarrying	1.67	−2.68	−4.71	2.86	−1.04
Manufacturing	22.69	6.01	2.23	3.92	−0.51
Electricity, gas and water	5.16	1.09	1.40	0.36	−0.91
Construction	7.46	1.97	−2.34	4.21	0.25
Trade and repair	26.95	5.90	−4.76	11.62	−0.33
Hotels and restaurants	2.76	−4.87	−6.96	0.81	0.94
Transport and communications	2.67	3.40	5.07	−1.06	−0.60
Financial activities	3.72	3.38	−3.58	6.17	−0.06
Real estate and rental	14.39	3.35	-	-	-
Public administration	7.26	1.29	-	-	-
Education	4.41	1.23	-	-	-
Health and social work	5.25	−0.72	-	-	-
Community, social and personal services	3.43	−0.80	-	-	-

In percent. Annual averages for 2001-2010, not accounting for capacity utilization.

C.2 Growth accounting for Czech manufacturing

	Industry's share	Growth rate	TFP	Contribultions of K	L	Capacity
Manufacturing, total	22.69	6.01	3.82	3.92	−0.51	−1.22
Food, beverages and tobacco	3.18	−1.15	−1.59	3.03	−1.23	−1.24
Textiles and leather	0.77	0.95	7.12	0.64	−5.67	−0.64
Wood	0.79	3.70	2.69	2.42	−0.62	−0.73
Paper and publishing	0.81	7.61	5.81	2.49	0.33	−1.05
Coke, petroleum and nuclear	0.01	-	-	-	-	-
Chemicals	0.95	7.58	6.03	3.53	−0.26	−1.71
Rubber and plastics	1.52	12.27	5.45	6.81	1.14	−1.29
Non-metallic mineral products	1.43	1.26	2.59	2.21	−2.23	−1.17
Basic metals	4.17	−0.33	−1.65	3.07	−0.34	−1.31
Machinery and equipment	2.84	8.74	5.49	4.20	−0.02	−0.94
Electrical and optical equipment	2.26	9.84	6.02	4.34	0.35	−0.93
Transport vehicles and equipment	3.21	16.16	9.64	6.32	1.04	−1.22
Other manufacturing	0.76	9.27	8.57	2.89	−1.05	−1.09

In percent. Annual averages for 2001-2010, accounting for capacity utilization.

D TFP residuals in Belarus relative to Czech Republic and Sweden, 2010

D.1 By sectors of economy

	Industry's share in Belarus	TFP residuals relative to Czech Republic	Sweden
Total	100.0	0.81	0.40
Agriculture	9.2	0.72	0.47
Mining and quarrying	1.3	1.35	1.01
Manufacturing	28.3	0.90	0.44
Electricity, gas and water	3.6	0.25	0.27
Construction	11.3	0.79	0.48
Trade and repair	13.8	2.12	1.09
Hotels and restaurants	1.2	0.98	0.44
Transport and communications	9.0	1.03	0.68
Financial activities	4.8	1.15	0.81
Real estate and rental	7.2	-	-
Public administration	4.1	-	-
Education	3.9	-	-
Health and social work	3.1	-	-
Community, social and personal services	2.4	-	-

Not accounting for capacity utilization.

D.2 By branches of manufacturing

	Industry's share in Belarus	TFP residuals relative to Czech Republic	Sweden
Manufacturing, total	28.3	0.95	0.46
Food, beverages and tobacco	6.7	1.24	0.57
Textiles and leather	1.9	0.73	0.27
Wood	0.7	0.68	0.29
Paper and publishing	0.7	0.83	0.46
Coke, petroleum and nuclear	1.2	-	0.54
Chemicals	4.7	2.02	-
Rubber and plastics	1.3	1.05	0.80
Non-metallic mineral products	2.2	0.91	0.47
Basic metals	2.2	1.20	0.61
Machinery and equipment	3.8	0.71	0.34
Electrical and optical equipment	1.7	0.65	0.22
Transport vehicles and equipment	1.5	0.63	0.58
Other manufacturing	1.1	1.12	0.47

Accounting for capacity utilization.